U.S. Department of the Interior
U.S. Geological Survey

MINERALS YEARBOOK

Metals and Minerals 2000

Volume I

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U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

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Foreword

This edition of the U.S. Geological Survey (USGS) Minerals Yearbook discusses the performance of the worldwide minerals and materials industries during 2000 and provides background information to assist in interpreting that performance. Content of the individual Minerals Yearbook volumes follows:

- Volume I, Metals and Minerals, contains chapters about virtually all metallic and industrial mineral commodities important to the U.S. economy. Chapters on survey methods, summary statistics for domestic nonfuel minerals, and trends in mining and quarrying in the metals and industrial minerals industries in the United States are also included.
- Volume II, Area Reports: Domestic, contains a chapter on the mineral industry of each of the 50 States and Puerto Rico and the Administered Islands. This volume also has chapters on survey methods and summary statistics for domestic nonfuel minerals.
- Volume III, Area Reports: International, is published as four separate reports. These regional reports contain the latest available minerals data on more than 190 foreign countries and discuss the importance of minerals to the economies of these nations and the United States. Each report begins with an overview of the region's mineral industries during the year. It continues with individual country chapters that examine the mining, refining, processing, and use of minerals in each country of the region and how each country's mineral industry relates to U.S. industry. Most chapters include production tables and industry structure tables, information about Government policies and programs that affect the country's minerals industry, and an outlook section.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the Minerals Yearbook are welcomed.

Charles G. Groat, Director

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Contacts

Information about the U.S. Geological Survey, its programs, staff, and products may be accessed on the World Wide Web at URL http://www.usgs.gov/ or by contacting the Earth Science Information Center at 1-888-ASK-MAPS. For specific information about this publication, contact Chief, Industrial Minerals Section, at (703) 648-4990; Chief, Metals Section, at (703) 648-4968; or Chief, Publication Services Section, Minerals Information Team, at (703) 648-4750. Additional minerals information may be accessed on the World Wide Web at http://minerals.usgs.gov/minerals/.

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Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook presents data on more than 80 minerals and materials that were obtained as a result of the information gathering activities of the U.S. Geological Survey.

The collection, compilation, and analysis of domestic mineral industry data were performed by the staff of the Minerals Information Team. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their responses are gratefully appreciated. Information obtained from individual firms by means of the U.S. Geological Survey canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted. The chapters on "Survey Methods" and "Statistical Summary" discuss in greater detail procedures for canvassing the mineral industry and the processing and evaluation of these data. Other information appearing in this volume was obtained from the trade and technical press, industry contacts, and additional sources; this cooperation is gratefully acknowledged.

Statistics on world production were compiled from numerous sources, including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the U.S. Department of Commerce, Bureau of the Census. The U.S. Geological Survey also was assisted by numerous cooperating State agencies.

John H. DeYoung, Jr.
Chief Scientist, Minerals Information Team

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MINERALS AND MATERIALS IN THE 20TH CENTURY—A REVIEW

By David E. Morse and Anna N. Glover

The period from 1900 to 2000 was marked by significant changes in the various industries that consume metals and industrial minerals and by major historic events that affected the way minerals are produced and used. This chapter is an overview of some of those changes. The pivotal changes to production and consumption of individual commodities are covered in the annual mineral commodity reviews in this 2000 edition of the U.S. Geological Survey's Minerals Yearbook.

The industrial revolution, which began in the late 1700s, continued through the 20th century, with the pace of technologic discovery and advancement increasing continually. The steam engine that had merely augmented wind, water, and muscle power before the advent of the 20th century gave way to diesel- and gasoline-fueled engines, which for the most part replaced older forms of energy used. The emergence of electric power and its widespread use caused an upsurge in technology that required less manpower and man-hours to complete the same tasks as were previously being done manually. The creation of the computer chip and the subsequent discoveries brought about more inventions the implementation of which facilitated the efficiency of a multitude of applications.

During the century, the Government increased its involvement in consumer protection and legislated various fields in response to activist movements. Legislation enacted by Congress through the century included civil rights, consumer protection, retirement plans, environmental protection, food and drugs, health care, labor/management relations, law enforcement, occupational safety, and social justice, as well as the New Deal, which was created to help the country's economy to grow after the Great Depression.

Experimentation and invention throughout the century in metallurgy, metals production technology, and metals forming and shaping resulted in the ability to produce metals of high purity, some alloys of high strength, others with corrosion resistance, and some with resistance to abrasion and erosion in chemically aggressive and high temperature regimes. Lightweight, low-density metals, such as aluminum and titanium, became important. Furnaces changed, refractories improved, continuous operations replaced batch processes, and electrochemical and hydrochemical processes augmented or replaced pyrometallurgical processes. In steelmaking, the basic oxygen and electric arc furnaces replaced the Bessemer and open-hearth furnaces. Glassmaking technology improvements resulted in tougher, stronger, and more brilliant glasses, and low thermal expansion borosilicate glass had improved shatter resistance. Chemical industry innovations improved mineral acid production; the lead chamber batch process for making sulfuric acid was replaced by the high-volume contact process with associated electric cogeneration plants. Lead oxide and barium/zinc-base lithopone white pigments were replaced by titanium dioxide, which improved whiteness and reduced the health hazard from heavy metal ingestion.

Systems to handle bulk materials improved greatly during the century. Salt and cement, which were routinely shipped in barrels in the early 1900s, were transferred at high rates on conveyor belts and pneumatic pipelines to covered hopper bottom dump railcars, which could haul 90 metric tons (t), and to over-the-road trailers that could move 20 to 30 t. Bulk handling facilities at ports had stacker/reclaimer systems that could move thousands of tons an hour. Open hopper railcars had specially designed couplers that allowed them to be emptied in rotary dumpers without uncoupling; belt and silo systems were used to fill unit trains, which were in continuous motion. Ocean-going bulk carriers capable of hauling hundreds of thousands of tons were in service, most with self-unloaders. Sulfur was shipped molten in special railcars and on uniquely designed barges and ships; bromine was transported in specially designed returnable containers and in unique trucks; one-half ton and one ton bags were in use. Machine power replaced the muscle power that was prevalent at the beginning of the century.

Over the span of the 20th century, the demand for metals and minerals in the United States grew from a little over 160 million tons to about 3.3 billion tons; the ratio of renewable to nonrenewable materials used declined from 40:60 to about 10:90 during the century. Nonfuel minerals accounted for nearly the entire nonrenewable materials demand in 1900, and nonrenewable organic materials accounted for only about 2 million tons. In 2000, consumption of nonrenewable organic materials was equal to the approximately 135 million metric tons of all metals consumed during that year in the United States. However, a significant percentage of nonrenewable organics was attributed to inorganic fillers, extenders, and pigments, which are industrial minerals.

Sectors of the Economy

Agriculture

The 20th century brought developments in the tools used in agricultural processes and in the seed and feed used in the various sectors of agriculture. New machinery, including the gasoline tractor, the grain combine harvester, and the mechanical cotton picker, shifted the emphasis from manpower and horsepower to the faster, more efficient machinery. The development and widespread use of pesticides and fertilizer produced more and better crops, while the creation and increasing use of engineered crops produced better livestock and enhanced agricultural production.

Between 1900 and the end of World War I, the demand for

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farm commodities was increasing. The postwar depression, however, severely affected farmers, until technology advancements that started in the 1930s aided in increasing the amount of land used for agricultural purposes. Although the Federal Government tried to help farmers with credit and cooperative management assistance, it was not until the creation of price supports, export subsidies, and soil conservation efforts in 1933 that agriculture received the help it needed. With the implementation of new technologies, the amount of land covered by farms in 1930 reached about 400 million hectares and remained at that level through 1980, and production during the same time period increased dramatically.

Communications

Of the discoveries of the 20th century, the radio, the television, and the telephone have been among the most important. Commercial radio broadcasting was established in 1920, and commercial television broadcasting, after World War II. By 1933, about two-thirds of American households had at least one radio, and about one-third had a telephone. By 1988, 97% of American households had at least one television set. Communications devices have had a profound impact on the culture, economy, lifestyle, and politics of the country. People have been able to watch events as they unfold, keep track of economic trends, and communicate with people half a world away. Media, politics, and entertainment have all benefitted from the advancements in the field of communications, as have emergency services, the economy, and many aspects of cultural life. The gap that time differences and distances had once created were being bridged by the end of the 20th century, bringing people, countries, and businesses closer together.

The metals and minerals industries have found a growing market in the various industries involved in communications, which purchase materials ranging from the metals required for cables and devices to nickel and lithium for batteries to germanium and silicon for semiconductors.

Construction

The 20th century saw the emergence of tall buildings, hydroelectric dams, high bridges, and highways that span the length and breadth of the country. Buildings of great height could be constructed because of steel-frame building techniques and the electric elevator. Skyscrapers, such as the World Trade Center and the Empire State Building in New York City and the Sears Tower in Chicago, which consumed large quantities of cement, ceramic tiles and sanitary ware, copper, glass, and steel, were almost exclusively a feature of the cities of North America for a good part of the 20th century. Late in the century, building of skyscrapers boomed in Asia.

Water power and associated dams, canals, and locks have been used for centuries; dams were used for flood control by maintaining water levels at navigable depths, to store water for drinking and irrigation, and to provide power. The widespread expansion of electric power grids and the constant increase in demand for electricity in the United States and worldwide prompted the construction of dams of unprecedented size during the 20th century.

Suspension bridges are impressive structures that transverse almost unbelievable distances. Although the first suspension bridges were built in the late 1800s, the highest and longest suspension bridges were built in the 20th century.

Another development of the 20th century was the increase in home ownership. Whereas in 1900, less than one-half of the U.S. population owned their own house, about two-thirds owned their house in 1990. Construction techniques and materials have changed drastically in the past 100 years to adapt to consumer, regulatory, and safety requirements and changing lifestyles, as well as those based on new technologies and materials.

Mining and Metal Processing

The technologic advancements that have been incorporated into consumer applications to make everyday living easier also have assisted industry to become more efficient, to produce more with fewer resources.

The mining and metal processing industries were among the first to take advantage of electricity, which was used to power trams and trains, underground and in-pit crushers, and conveyor systems that, combined with employing diesel- and diesel/electric-haulage vehicles, replaced the draft animals. By the end of the 20th century, the mining industry used machines of great size and power that operated at astounding rates and could mine continuously in underground mines and in surface operations. Additionally, innovative materials, such as synthetic greases and lubricants and metal alloys, were employed in critical wear areas to enhance their reliability. The various technologic advancements in mining and related technologies that took place during the century increased the quantity of material produced per employee.

Also during the 20th century, legislation to protect the health and safety of employees and regulations to protect the environment and the mining industry were promulgated. Mining and metal processing waste was regulated in an effort to protect the environment, and laws were enacted that would help miners who were injured on the job or who got sick because of their working conditions.

Innovation was not restricted to mining machinery and mining practices but also to ore processing and mineral separation. Mineral processing can have one or more of several goals depending on the nature of the ore and the desired end product. Early in the century, simple crushing, screening, and washing operations were augmented by such improvements as log washing, jigging, heavy media separation, and tabling that separated mineral species based on density. Later, froth flotation of finely crushed materials produced concentrates from low-grade ore; in-situ solution mining, solvent extraction, and heap leaching proved to be cost-effective ways of producing uranium, copper, and gold, respectively; and the unique Frasch method of underground melting of sulfur was practiced for most of the century. By combining processes, mining companies were able to produce multiple products from a single ore, which meant that they could mine ore bodies that would have been avoided early in the century owing to their leanness and could thus make a profit from the leaner ores.

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Consumer Goods

There has been much technologic advancement since the early 19th century. Few fields have benefited more than the one that consists of applications used by consumers everyday. Such appliances as stoves, microwave ovens, refrigerators, and washing machines have made completing everyday tasks easier, and such applications of technology as televisions, telephones, computers, and compact disk (CD) players have provided a greater degree of comfort and entertainment than has been possible for more people than ever before. Some of these same devices have also facilitated the creation and operation of small businesses and self-employment, increasing the Nation's standard of living and helping the country's economy grow.

Health Services

The field of medicine and drugs has changed significantly over the past century. Where only a few drugs were used extensively and medical science was still in its early stages of evolution before 1900, the rate of advances grew drastically during the century and especially after World War II with such advances as genetic mapping, immunosuppressive drugs, magnetic resonance and x-ray imaging, and medical transplantation. One of the contributions of genetic mapping is the production of genetically engineered bacteria designed to break down oil slicks and industrial waste products.

Military

The 20th century was a time of great invention of military and defense applications. The airplane was used in World War I as a military machine for the first time and was enhanced during most of the century. The jet engine made the airplane one of the most widely used forms of commercial transportation, and developments such as breaking the sound barriers and the ability to take off and land vertically have made the airplane valuable to the defense of the Nation.

Other applications that were created by or for the military have found widespread use in consumer applications. One of the biggest developments of the late 20th century, the Internet, was initially developed as a network for the Department of Defense. The laser, which is used in such applications as CD and digital video disk (DVD) players, was created for military applications.

Transportation

At the beginning of the 20th century, the U.S. railroad system connected every major city, town, and hamlet in the Nation. Thousands of trains daily came and went from major cities. Electric streetcars serviced cities, and subways were set up in such cities as Boston and New York. Horses, carriages, mules, and wagons traversed cobble stone streets in the cities and dirt and gravel roads in rural areas. Steam-powered ferries plied the Nation's rivers, bays, inlets, and sounds. The railroads were major consumers of iron and steel for locomotives, rails, and bridges and of aggregates for roadbeds. Trolleys and subways were also consumers of iron and steel, and used copper for motors, switches, and lighting.

The adaptation of the combustion-ignition engine to the carriage led to a significant change in America by the 1920s. From a few "horseless carriages" in 1900 to millions of motorcars in the 1920s, the effects were astounding. Gone were the millions of draft animals, the stables and feed stores, and the mountains of dung. The almost universal adoption of the motorcar resulted in a cry for better roads and bridges, which had a positive effect on the construction industry, which was a major consumer of copper, cement, glass, sand and gravel, steel, and stone. The automobile industry became a major consumer of copper, glass, iron and steel, lead, and zinc. The effect of the automobile was not restricted to draft animals; ferries and railroads keenly felt it. Bridges of unprecedented size replaced ferries at many crossings; passenger rail service became unprofitable by 1930. Diesel-electric traction engines began replacing steam locomotives in the 1930s, and the transition was essentially complete by the early 1950s. By 1940, the Nation had over 3 million miles (about 5 million kilometers) of roads, of which only about one-half were paved.

After World War II, passenger air service greatly expanded, while buses and trucks proved more efficient than rail for service to smaller cities and to towns. Jet engine air passenger service, which was established in the late 1950s, had an additional adverse effect on long distance rail passenger service by shortening the time required for a journey.

The oil embargo of 1973 and adherence to government regulations on emissions and fleet gas mileage altered the automobile such that lighter weight metals and plastics were used to replace iron and steel where possible. Photochemical smog from engine exhaust was a problem in many areas. The automobile was partly responsible for urban sprawl late in the century. The population increase in the last half of the century, which led to urban sprawl and expansion of the suburbs, resulted in a great expansion of water and sewer, electric, telephone, and other public utilities systems, more and bigger roads, larger homes, more schools, more shopping centers, increased emergency services and law enforcement, more hospitals, and larger airports. The expansion placed high demands on the products of the minerals industry.

In 1900, one could cross the continent by rail in about a week; by 2000, one could go the same distance by air in under 8 hours. An ocean voyage to Europe was also about a week's journey; it was only a 10-hour trip by air in 2000. Much rail and most ocean vessel passenger service had been replaced by air service by the end of the 20th century. The movement of goods, however, remained the domain of trains, barges, and ocean vessels. Intermodal containers that could be transferred from rail to ship to truck without unloading were developed to enhance efficiency.

Environmental Considerations

Over the course of the century, the attitude that the Earth was nothing more than resources to be used changed slowly, and by the 1960s, the concept of mankind being stewards of the Earth started becoming more prevalent. In response to growing public demand for a cleaner environment, the government established standards to protect public health and to limit damage to

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animals, crops, vegetation, and buildings. Some of the early results were a sharp decline in atmospheric lead and sulfur dioxide (SO_2) emissions.

Control of SO_2 emissions, which help reduce acid rain, affected different parts of the nonfuel minerals industry in opposing directions; recovery of SO_2 at smelters as sulfuric acid was costly and resulted in a byproduct that was not always readily salable. Although recovery of SO_2 at powerplants is also costly, it increased demand for sorbents, primarily lime and limestone, and the building materials needed to construct flue gas desulfurization facilities. The sulfur content of liquid fuels also was regulated and reduced SO_2 emissions from automobiles, trucks, and airplanes.

Since the late 1960s, recycling also became important and contributed to resource conservation, which became another issue of great concern for activists. Recycling is especially important because it removes material from the waste stream so disposal is not needed and it supplies raw materials that can go into new products usually at substantial energy savings compared with products made from virgin materials.

Conclusion

Patterns of consumption per capita of metals and minerals for developed economies have been stable in the latter part of the 20th century, and while there were lower rates of consumption in many developing countries, a number of developing countries had growing consumption per capita. The growth of metals and minerals consumption in developing countries could have a great impact on world mineral consumption.

In the future, satisfying the relatively modest per capita material requirements of these developing countries could strain industrial and financial systems and—potentially—environmental quality. Fostering sustainable development to meet such needs could be key to world peace and stability and could represent one of the major challenges for the physical and social sciences communities and the developed world for the next century.

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SURVEY METHODS FOR NONFUEL MINERALS

By Kenneth W. Mlynarski

The U.S. Geological Survey (USGS) collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the base for tracking and assessing the health of the minerals sector of the U.S. economy.

The USGS data collection activity was instituted by the 47th Congress in the appropriations act of August 7, 1882 (22 Stat. 329), which placed the collection of mineral statistics on an annual basis. The most recent authority for the USGS survey activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479, 96th Congress). This act strengthens protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

Data Collection Surveys

The USGS begins the collection of domestic nonfuel minerals and materials statistics by appraising the information requirements of Government and private organizations of the United States. Requirements that can be met by collecting data from minerals establishments are posed as questions on USGS surveys. Figure 1 shows a typical survey form.

Specific questions about mineral commodity activities, such as production, consumption, and shipments, are structured in the survey forms to provide meaningful aggregated data. Thus, the entire mineral economic cycle from production through consumption is covered by 140 monthly, quarterly, semiannual, and annual surveys.

After the survey form has been designed, a list of the appropriate establishments to be canvassed is developed. Many sources are used to determine which companies, mines, plants, and other operations should be included on the survey mailing list. State geologists, Federal organizations (e.g., Mine Safety and Health Administration), trade associations, industry representatives, and trade publications and directories are some of the sources that are used to develop and update survey listings. With few exceptions, a complete canvass of the list of establishments is used rather than a sample survey. The iron and steel scrap industry is one of the exceptions where a sample survey is conducted.

The Paperwork Reduction Act requires that any Government agency wanting to collect information from 10 or more individuals or establishments must first obtain approval from the Office of Management and Budget (OMB). The OMB approves the need to collect the data and protects industry from unwarranted Government paperwork.

Survey Processing

The USGS surveys approximately 18,000 establishments. Each year, the USGS mails about 40,000 forms for 140 different surveys. Each completed survey form returned to the USGS undergoes extensive analysis to ensure the highest possible accuracy of the mineral data. The statistical staff monitors all surveys to ensure that errors are not created by reporting in physical units different from the units requested on the form. Relations between related measures, such as produced crude ore and marketable crude ore, are analyzed for consistency. Engineering relations, such as recovery factors from ores and concentrates, also are used. The totals for each form are verified, and currently reported data are checked against prior reports to detect possible errors or omissions.

For the majority of the surveys, which are automated, the forms are reviewed to ensure that data are complete and correct before entering into the computer database. The computer is programmed to conduct a series of automated checks to verify mathematical consistency and to identify discrepancies between the data reported and logically acceptable responses.

The USGS is modernizing and automating the minerals information survey-processing and data-dissemination functions. Automated commodity data system functions include computerized preparation of statistical tables, the use of desktop publishing to integrate text and tables, and electronic dissemination through the Internet. Information on minerals and mineral-related publications also is available through an easy-to-use automated fax response system known as MINES FaxBack.

Survey Responses.—To enable the reader to understand better the basis on which the statistics are calculated, each commodity annual report includes a section about domestic data coverage. This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production or consumption for nonrespondents.

To produce reliable aggregated data, the USGS uses efficient procedures for handling instances of nonresponse. Failure to return the initial survey form results in a second mailing of the form. If the second form is not returned, then telephone calls are made to the nonrespondents. The followup calls provide the necessary data to complete the survey forms and/or to verify questionable data entries. Periodic visits to minerals establishments also are made by USGS mineral commodity specialists to gather missing data and to explain the importance of the establishment's reporting. By describing the use of the published statistics and showing the impact of nonresponse, the USGS strives to encourage respondents to give complete and accurate replies.

The OMB publication "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate is 75% of the panel surveyed. In addition, the USGS strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics.

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Response rates are periodically reviewed. For those surveys not meeting the minimum reporting level, procedures are developed and implemented to improve response rates.

Estimation for Nonresponse.—When efforts to obtain a response to a survey fail, estimation or imputation techniques must be used to account for missing data. Some of the estimation methods depend on knowledge of prior establishment reporting, and other techniques rely on external information to estimate the missing data. When survey forms are received after the current publication has been completed, the forms are edited, necessary imputations are made for missing data, and the survey database is updated. The revised data are reported in later publications.

Protection of Proprietary Data.—The USGS relies on the cooperation of the U.S. minerals industry to provide the mineral data that are presented in this and other USGS publications. Without a strong response to survey requests, the USGS would not be able to present reliable statistics. The USGS, in turn, respects the proprietary nature of the data received from the individual companies and establishments. To ensure that proprietary rights will not be violated, the USGS analyzes each of the aggregated statistics to determine if the data reported by an individual establishment can be deduced from the aggregated statistics. If, for example, only two significant producers of a mineral commodity are in a given State, then the USGS will not publish the State total because either producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the withheld, or W, entries in the published tables. If a company gives permission in writing, however, then the USGS will publish the data as long as the data from other respondents are protected from disclosure.

International Data

International data are collected by USGS country specialists and international data coordinators. The data are gathered from various sources, which include published reports of foreign Government mineral and statistical agencies, international organizations, the U.S. Department of State, the United Nations, the Organization of Petroleum Exporting Countries, and personal contact by specialists traveling abroad. Each February, annual minerals questionnaires that are sent to foreign organizations request them to provide estimates of mineral production for the host country for the preceding year. Missing data are estimated by USGS country specialists on the basis of historical trends and the specialist's knowledge of current production capabilities in each country.

Publications

The USGS disseminates current and historical minerals information through a broad range of printed publications.

The Minerals Yearbook summarizes annually, on a calendar-year basis, the significant economic and technical developments in the mineral industries. Three volumes are issued each year—volume I, Metals and Minerals; volume II, Area Reports—Domestic; and volume III, Area Reports—International. Volume I presents, by mineral commodity, salient statistics on production, trade, consumption, reserves, and other measures of economic activity. The chapters are issued separately as annual Mineral Industry Surveys (MIS) before the bound volume is available. Volume II reviews the U.S. minerals industry by State and island possessions. Volume III is published as four separate regional reports that cover more than 190 foreign countries. These reports contain individual country chapters that examine the mining, refining, processing, and use of minerals in each country in the region and how they relate to U.S. industry.

The MIS contain timely statistical and economic data on minerals. The surveys are designed to keep Government agencies and the public, particularly the mineral industry and the business community, informed of trends in the production, distribution, inventories, and consumption of minerals. Frequency of issue depends on the demand for current data. The MIS are released monthly, quarterly, semiannually, and annually.

Mineral Commodity Summaries (MCS), which is an up-to-date summary of about 80 nonfuel mineral commodities, is the earliest Government publication to furnish estimates that cover the previous year's nonfuel mineral industry data. It contains information on the domestic industry structure, Government programs, tariffs, 5-year salient domestic statistics, and a summary of significant events, trends, and issues in the international minerals industry during the past year.

Metal Industry Indicators (MII), which is published monthly, contains indexes that measure the current and future performance of five U.S. metal industries. For each of the five industries, a composite coincident index and a composite leading index have been developed based on procedures and data similar to those used to construct the Conference Board's coincident and leading cyclical indicators for the national economy. Leading and coincident indexes for the stone, clay, glass, and concrete products industry, which measure the current and future performance of the industrial minerals industry, also are published monthly. The indexes were designed by using the same procedures as the USGS metal composite indexes.

The MIS and the MII are available at no charge from Publication Distribution, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236, (412) 386-6156 or (412) 386-6160. Orders may be placed via electronic mail to pitpdrequests@cdc.gov. The Minerals Yearbooks and the MCS, may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, (202) 512-1800.

Some minerals information publications are also available on a CD-ROM format. The Minerals and Materials Information CD-ROM, which contains the Minerals Yearbooks, the MCS, and other publications, is updated three times per year. It is available from the Government Printing Office at the address and telephone number listed above.

Electronic Data Dissemination

In addition to the USGS printed publications, current

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information on minerals and mineral-related publications from the USGS is available through an easy-to-use site on the World Wide Web. The URL is http://minerals.usgs.gov/minerals. All minerals information series publications from 1996 are available to view or download. The web site also provides information on other products and contacts for minerals information and links to other mineral-related sites on the World Wide Web.

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FIGURE 1
A TYPICAL SURVEY FORM

USGS Form 9-4045-M
Fer. (rev. 9/11/98)

OBM Control No. 1028-0068
Approval expires: 09/30/01

USGS
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A03

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
986 NATIONAL CENTER
RESTON, VIRGINIA 20192

IRON ORE (Usable ore)

INDIVIDUAL COMPANY DATA – PROPRIETARY

Unless authorization is granted in the section above the signature, the data furnished in this report will be treated in confidence by the Department of the Interior, except that they may be disclosed to Federal defense agencies, or to the Congress upon official request for appropriate purposes. Unless objection is made in writing to the USGS, the information furnished in this report may be disclosed to the respondent's State Geological Survey (or similar State agency) if the State has appropriate safeguards to prevent disclosing company proprietary data.

(Please correct if name or address has changed)

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Public voluntary reporting burden for this collection of information is estimated to average 30 MINUTES per response. A Federal agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. Comments regarding this collection of information should be directed to: U.S. Geological Survey, Statistics and information Systems Section, 988 National Center, Reston, VA 20192; and/or Desk Officer for the Department of the Interior, Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503. **Please do not mail survey forms to these addresses.**

Collection of nonfuel minerals information is authorized by Public Law 96-479 and the Defense Production Act. This information is used to support executive policy decisions pertaining to emergency preparedness, national defense, and analyses for minerals legislation and industrial trends. The USGS relies on your voluntary and timely response to assure that its information is complete and accurate.

Please return this form in the enclosed envelope or fax it to the above toll-free number by the **15TH OF THE MONTH** following the reporting period. Complete a separate form for each mineral establishment that was active during the reporting period. A minerals establishment is defined as a single physical location where mineral operations are conducted; for example, a mine only, a mine and preparation plant, or a preparation plant only. If you do not have exact data, please enter your best estimates and mark with an /e. Use zero (0) when appropriate. Do not report decimals or fractions. Round to the nearest whole number. If you have nothing to report, please complete Section 1, sign, and return the form. Please use the space for "Remarks" to provide any specific information that will help us in the use or interpretation of the data. Any statement on the effect of changes in economic conditions upon the reporting establishment will be useful. Additional forms are available upon request.

If you have any questions concerning completion of this form, please contact the Mineral Commodities Data Unit, U.S. Geological Survey, 985 National Center, Reston, VA 20192, Telephone (703) 648-7960.

SECTION 1. Mine or group covered by this report.

Name _____ State _____ County _____

SECTION 2. Stocks, production, and shipments of usable ore for the report month.

Report only ore products as shipped to consumer, such as direct-shipping ore, concentrate, or agglomerates.
Report ores produced in the United States only; do not include imports.

Usable ore (1)	Code	Weight unit Mark (X) one (2) Long tons (4)	Weight unit Mark (X) one (2) Metric tons (6)	Physical inventory Adjustment only (3)	Beginning stocks (4)	Production (5)	Shipments (6)	Ending stocks (7)
Iron ore (containing less that 5% Mn, natural.....	201							

SECTION 3. Please indicate any mines opened or closed by your company during the month.

Remarks:

Name of person to be contacted regarding this report			Tel. area code	No.	Ext.
Address	No.	Street	City	State	ZIP Code

May tabulations be published which could indirectly reveal the data reported above? ☐ (1) Yes ☐ (2) No

Signature	Title	Date

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STATISTICAL SUMMARY

By Stephen D. Smith

This annual report summarizes data on crude nonfuel mineral production[1] for the United States, its island possessions, and the Commonwealth of Puerto Rico.

Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this annual report is what is termed "mine output." This term refers to minerals or ores in the form in which they are first extracted from the ground, but customarily may include the output from auxiliary processing at or near the mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. For copper, gold, lead, silver, and zinc, the quantities shown are recorded on a mine basis (as the recoverable content of ore sold or treated). The values assigned to the quantities, however, are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for the metal. Values shown are in current dollars, with no adjustments made to compensate for changes in the purchasing power of the dollar.

The annual total value of all nonfuel mineral production in the United States increased almost 1% to $39.4 billion in 2000, with metals increasing almost 4% to $10.2 billion and industrial minerals decreasing less than 1% to $29.2 billion compared with those of 1999. Nine of the mineral commodities produced in the United States in 2000 had an individual total production value that was greater than $1 billion. These commodities were, in descending order, stone (crushed), cement (portland), sand and gravel (construction), gold, copper, iron ore (usable), lime, salt, and zinc. They composed almost 79% of the U.S. total production value (table 1).

In 2000, 13 States produced nonfuel mineral commodities with individual total production values of greater than $1 billion. These States were, in descending order, California, Nevada, Arizona, Texas, Florida, Michigan, Georgia, Minnesota, Utah, Missouri, Pennsylvania, Alaska, and New York. They composed slightly over 59% of the U.S. total production value (table 3).

---

[1]The terms "nonfuel mineral production" and related "values" encompass variations in meaning, depending on the minerals or mineral products. Production may be measured by mine shipments, mineral commodity sales, or marketable production (including consumption by producers) as is applicable to the individual mineral commodity.

All 2000 USGS mineral production data published in this chapter are as of January 2002. For some commodities such as construction sand and gravel, crushed stone, and portland cement, data are updated periodically. To obtain the most current information, please contact the appropriate USGS mineral commodity specialist. A telephone listing for the specialists may be retrieved over the Internet at URL http://minerals.usgs.gov/minerals/contacts/ comdir.html or by calling USGS information at (703) 648-4000 for the specialist's name and number. All Mineral Industry Surveys–mineral commodity, State, and country–also may be retrieved over the Internet at URL http://minerals.usgs.gov/minerals.

Values, percentage calculations, and rankings for 2000 may vary from the Minerals Yearbook, Area Reports: Domestic 2000, Volume II, owing to revision of preliminary 2000 to final 2000 data.

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TABLE 1
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998		1999		2000	
		Quantity	Value	Quantity	Value	Quantity	Value
Metals:							
Antimony 3/	metric tons	489	W	450 r/	W	W	W
Beryllium concentrates	do.	6,080	7	5,070	6	4,510	5
Copper 4/		1,860	3,220,000	1,600	2,680,000	1,440	2,810,000
Gold 4/	kilograms	366,000	3,480,000	341,000	3,070,000	353,000	3,180,000
Iron ore, usable		63,200	1,970,000	58,500 r/	1,550,000	61,000	1,560,000
Iron oxide pigments, crude	metric tons	46,100	7,290	44,100	7,740	57,100	4,470
Lead 4/	do.	481,000	480,000	503,000	485,000	457,000	439,000
Magnesium metal	do.	106,000	344,000	W	W	W	W
Molybdenum concentrates 3/	do.	52,100	200,000	42,800 r/	251,000 r/	41,100	232,000
Palladium 3/	kilograms	10,600	98,500	9,800	114,000	10,300	228,000
Platinum 3/	do.	3,240	39,000 r/	2,920	35,600	3,110	69,200
Rare-earth metal concentrates e/ 3/	metric tons	5,000	14,400	5,000	14,400	5,000	W
Silver 4/	do.	2,060	368,000 r/	1,950	329,000	1,860	300,000
Zinc 4/	do.	709,000	804,000	771,000 r/	909,000 r/	786,000	1,020,000
Combined value of mercury, titanium concentrates, vanadium, zirconium concentrates, and values indicated by symbol W		XX	145,000	XX	368,000	XX	343,000
Total		XX	11,200,000	XX	9,810,000	XX	10,200,000
Industrial minerals, excluding fuels:							
Asbestos	metric tons	5,760	W	7,190	W	5,260	W
Barite		476	11,400	434	11,100	392	9,840
Boron		1,170	486,000	1,220	630,000	1,070	557,000
Bromine	metric tons	230,000	162,000	239,000	213,000	228,000	206,000
Cement:							
Masonry		3,990	391,000 e/	4,380	452,000 e/	4,330	451,000 e/
Portland		79,900	6,030,000 e/	81,600	6,280,000 e/	83,500	6,440,000 e/
Clays:							
Ball		1,130	51,100	1,200	48,000	1,140	48,400
Bentonite		3,820	176,000	4,070	176,000	3,760	155,000
Common		24,500 r/	135,000 r/	24,800 r/	145,000 r/	23,700	135,000
Fire		410	7,520	402	6,770	476	7,560
Fuller's earth		2,420	233,000	2,560	231,000	2,910	254,000
Kaolin		9,640	1,060,000	9,160	948,000	8,800	929,000
Diatomite		725	180,000	747	178,000	677	173,000
Feldspar	metric tons	820,000	40,800	875,000	42,700	790,000	44,500
Garnet, industrial	do.	74,000	7,070	60,700	6,170	60,200	7,060
Gemstones		NA	14,300	NA	16,100	NA	17,200
Gypsum, crude		19,000	132,000	22,400	157,000	19,500	165,000
Helium:							
Crude	million cubic meters	33	29,700	63	57,200	62	56,600
Grade-A	do.	112 r/	219,000	117	233,000	127	251,000
Iodine	metric tons	1,490	22,700	1,620	23,800	1,470	21,500
Kyanite e/		90	13,200	90	12,700	90	13,400
Lime		20,100	1,250,000 r/	19,600 r/	1,180,000 r/	19,600	1,180,000
Mica, crude		102 r/	14,500 r/	102 r/	15,900 r/	104	14,100
Peat		791	19,200	834	22,100	847	22,700
Perlite, crude	metric tons	685,000	21,800	711,000	23,800	672,000	22,700
Phosphate rock, marketable		44,200	1,130,000	40,600	1,240,000	38,600	932,000
Potash		3,000	330,000	2,500	280,000	2,600	290,000
Pumice and pumicite	metric tons	583,000	12,600	643,000	17,800	697,000	16,900
Salt		40,800	986,000	44,400	1,110,000	43,300	1,040,000
Sand and gravel:							
Construction		1,070,000	4,910,000	1,110,000	5,250,000	1,120,000	5,390,000
Industrial		28,200	513,000	28,900	538,000	28,400	556,000
Silica stone 5/	metric tons	438	3,440	475	3,060	312	4,610
Soda ash		10,100	842,000	10,200	779,000	10,200	748,000
Stone, crushed 6/		1,510,000	8,130,000	1,540,000	8,240,000	1,560,000	8,390,000
Tripoli	metric tons	79,600	16,900	84,900	20,200	72,000	15,900 e/
Vermiculite	do.	W	W	175,000 e/	W	150,000 e/	W
Zeolites	do.	38,500	NA	40,100	NA	(7/)	NA

See footnotes at end of table.

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TABLE 1--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1998		1999		2000	
	Quantity	Value	Quantity	Value	Quantity	Value
Industrial minerals, excluding fuels--Continued:						
Combined value of brucite, emery, greensand marl, lithium, magnesite, magnesium compounds, olivine, pyrophyllite (crude), staurolite, stone (dimension), sulfur (Frasch), talc (crude), vermiculite (crude), wollastonite and values indicated by symbol W	XX	614,000	XX	675,000	XX	619,000
Total	XX	28,200,000 r/	XX	29,300,000 r/	XX	29,200,000
Grand total	XX	39,400,000	XX	39,100,000 r/	XX	39,400,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value." XX Not applicabl
1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Content of ore and concentrate.
4/ Recoverable content of ores, etc.
5/ Includes grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
6/ Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.
7/ Withheld to avoid disclosing company proprietary data.

TABLE 2
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 2000

(Principal States based upon quantity unless otherwise noted)

Mineral	Principal States	Other States (alphabetical order)
Antimony 1/	ID	
Asbestos	CA	
Barite	NV, GA, TN	
Beryllium concentrate	UT	
Boron	CA	
Bromine	AR and MI	
Brucite	NV and TX	
Cement:		
Masonry	FL, CA, IN, SC, AL	AZ, AR, CO, GA, HI, IA, KS, KY, ME, MD, MI, MO, MT, NE, NM, NY, OH, OK, PA, SD, TN, TX, VA, WV.
Portland	CA, TX, PA, MI, MO	All other States, except AK, CT, DE, LA, MA, MN, NH, NJ, NC, ND, RI, VT, WI.
Clays:		
Ball	TN, TX, KY, MS	
Bentonite	WY, MT, AL, MS, UT	AZ, CA, CO, NV, OR, TX.
Common	NC, TX, AL, GA, OH	All other States, except AK, DE, HI, ID, NV, NH, RI, VT, WI.
Fire	MO, OH, SC, CA, CO	KY and NM.
Fuller's earth	GA, MS, IL, MO, FL	CA, KS, NV, TN, TX, VA.
Kaolin	GA, AL, SC, CA, TX	AR, FL, NV, NC, TN.
Copper 1/	AZ, UT, NM, MT, NV	MO, ID, AK.
Diatomite	CA, NV, OR, WA	
Emery	OR	
Feldspar	NC, VA, CA, GA, OK	ID and SD.
Garnet, industrial	ID, NY, MT	
Gemstones, natural 2/	TN, AZ, CA, NV, UT	All other States.
Gold 1/	NV, UT, CA, AK, MT	AZ, CO, ID, NM, SD, WA.
Greensand marl	NJ	
Gypsum, crude	OK, IA, MI, NV, TX	AZ, AR, CA, CO, IN, KS, LA, MI, NM, NY, OH, SD, UT, WA, WY.
Helium:		
Crude	KS, TX, OK	
Grade-A	KS, WY, TX, CO, OK	UT.
Iodine	OK	
Iron ore, usable	MN, MI, NM, SD	
Iron oxide pigments, crude	GA, MO, MI, AL, VA	AZ.
Kyanite	VA	
Lead 1/	MO, AK, ID, MT, TN	NV and NY.
Lime	MO, KY, AL, OH, TX	All other States, except AK, CT, DE, FL, HI, KS, ME, MD, MS, NH, NJ, NY, NC, RI, VT.
Lithium	NV	
Magnesite	NV	

See footnotes at end of table.

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TABLE 2--Continued
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 2000

(Principal States based upon quantity unless otherwise noted)

Mineral	Principal States	Other States (alphabetical order)
Magnesium compounds	MI, FL, UT, DE, CA	
Magnesium metal	WA and UT	
Mercury	NV	
Mica, crude	NC, NM, SC, SD, GA	VA.
Molybdenum	AZ, UT, CO, ID, MT	NM.
Olivine	NC and WA	
Palladium 1/	MT	
Peat	FL, MI, MN, IN, IL	IA, ME, MT, NJ, NY, NC, OH, PA, WA, WV, WI.
Perlite	NM, OR, AZ, UT, CA	NV and ID.
Phosphate rock	FL, NC, ID, UT	
Platinum 1/	MT	
Potash	NM, UT, MI	
Pumice and pumicite	OR, CA, NM, ID, AZ	KS.
Pyrophyllite, crude 3/	NC and CA	
Rare-earth metal concentra	CA	
Salt	LA, TX, NY, OH, KS	AL, AZ, CA, MI, NV, NM, OK, TN, UT, WV.
Sand and gravel:		
Construction	CA, TX, MI, AZ, OH	All other States.
Industrial	IL, MI, CA, WI, TX	All other States, except AK, CT, DE, HI, KY, ME, MA, MT, NH, OR, SD, UT, VT, WY.
Silica stone 4/	AR and WI	
Silver 1/	NV, AK, ID, AZ, UT	CA, CO, MO, MT, NM, SD, WA.
Soda ash	WY and CA	
Staurolite	FL	
Stone:		
Crushed	TX, PA, FL, GA, IL	All other States, except DE.
Dimension	IN, VT, WI, TX, GA	All other States except AK, DE, FL, HI, IL, IA, KY, LA, MS, NE, NV, NJ, ND, OR, RI, WY.
Sulfur, Frasch	LA	
Talc, crude 3/	MT, TX, VT, NY, OR	
Titanium concentrates:		
Ilmenite	FL and VA	
Rutile	FL	
Tripoli	IL, OK, AR, PA	
Vanadium 1/	ID	
Vermiculite, crude	SC and VA	
Wollastonite	NY	
Zeolites	NM, TX, OR, NV, AZ	ID and CA.
Zinc 1/	AK, TN, MO, NY, MT	ID.
Zirconium concentrates	FL and VA	

1/ Content of ores, etc.
2/ Principal producing States based on value.
3/ Formerly part of mineral grouping "Talc and Pyrophyllite."
4/ Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

TABLE 3
VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2000 1/

State	Value (thousands)	Rank	Percentage of total	Principal minerals, in order of value
Alabama	$930,000	16	2.36	Cement (portland), stone (crushed), lime, sand and gravel (construction), cement (masonry).
Alaska	1,140,000	12	2.89	Zinc, gold, lead, silver, sand and gravel (construction).
Arizona	2,510,000	3	6.38	Copper, sand and gravel (construction), cement (portland), molybdenum concentrates, stone (crushed).
Arkansas	484,000	30	1.23	Bromine, stone (crushed), cement (portland), sand and gravel (construction), gypsum (crude).
California	3,270,000	1	8.30	Sand and gravel (construction), cement (portland), boron, stone (crushed), gold.
Colorado	592,000	26	1.50	Sand and gravel (construction), cement (portland), stone (crushed), gold, molybdenum concentrates.
Connecticut 2/	112,000	42	0.29	Stone (crushed), sand and gravel (construction), stone (dimension), clays (common), gemstones.
Delaware 2/	12,400	50	0.03	Sand and gravel (construction), magnesium compounds, gemstones.
Florida	1,820,000	5	4.62	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Georgia	1,620,000	7	4.11	Clays (kaolin), stone (crushed), cement (portland), clays (fuller's earth), sand and gravel (construction).
Hawaii	92,000	44	0.23	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry), gemstones.
Idaho	358,000	33	0.91	Phosphate rock, silver, sand and gravel (construction), molybdenum concentrates, lead.
Illinois	913,000	17	2.32	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial), lime.
Indiana	695,000	22	1.77	Stone (crushed), cement (portland), sand and gravel (construction), lime, cement (masonry).

See footnotes at end of table.

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TABLE 3--Continued
VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2000 1/

State	Value (thousands)	Rank	Percentage of total	Principal minerals, in order of value
Iowa	$503,000	28	1.28	Cement (portland), stone (crushed), sand and gravel (construction), gypsum (crude), lime.
Kansas	629,000	23	1.60	Cement (portland), helium (grade-A), salt, stone (crushed), helium (crude).
Kentucky	501,000	29	1.27	Stone (crushed), lime, cement (portland), sand and gravel (construction), clays (ball).
Louisiana	325,000	35	0.83	Salt, sulfur (Frasch), sand and gravel (construction), stone (crushed), sand and gravel (industrial).
Maine	95,500	43	0.24	Sand and gravel (construction), cement (portland), stone (crushed), cement (masonry), peat.
Maryland 2/	358,000	34	0.91	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry), stone (dimension).
Massachusetts 2/	200,000	39	0.51	Stone (crushed), sand and gravel (construction), stone (dimension), lime, clays (common).
Michigan	1,640,000	6	4.17	Cement (portland), iron ore (usable), sand and gravel (construction), stone (crushed), magnesium compounds.
Minnesota	1,460,000	8	3.70	Iron ore (usable), sand and gravel (construction), stone (crushed), stone (dimension), sand and gravel (industrial).
Mississippi	149,000	41	0.38	Sand and gravel (construction), clays (fuller's earth), cement (portland), stone (crushed), sand and gravel (industrial).
Missouri	1,370,000	10	3.48	Stone (crushed), cement (portland), lead, lime, zinc.
Montana	596,000	25	1.51	Palladium, gold, platinum, cement (portland), sand and gravel (construction).
Nebraska 2/	83,700	45	0.21	Cement (portland), stone (crushed), sand and gravel (construction), lime, cement (masonry).
Nevada	2,980,000	2	7.56	Gold, sand and gravel (construction), silver, lime, cement (portland).
New Hampshire 2/	57,100	47	0.14	Sand and gravel (construction), stone (crushed), stone (dimension), gemstones.
New Jersey 2/	291,000	37	0.74	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), greensand marl, peat.
New Mexico	786,000	18	2.00	Copper, potash, sand and gravel (construction), cement (portland), stone (crushed).
New York	1,020,000	13	2.58	Stone (crushed), salt, cement (portland), sand and gravel (construction), zinc.
North Carolina	744,000	19	1.89	Stone (crushed), phosphate rock, sand and gravel (construction), sand and gravel (industrial), feldspar.
North Dakota	35,200	48	0.09	Sand and gravel (construction), lime, stone (crushed), clays (common), sand and gravel (industrial).
Ohio	999,000	14	2.54	Stone (crushed), sand and gravel (construction), salt, lime, cement (portland).
Oklahoma	473,000	31	1.20	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial), gypsum (crude).
Oregon	299,000	36	0.76	Stone (crushed), sand and gravel (construction), cement (portland), diatomite, lime.
Pennsylvania 2/	1,250,000	11	3.17	Stone (crushed), cement (portland), sand and gravel (construction), lime, cement (masonry).
Rhode Island 2/	20,300	49	0.05	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), gemstones.
South Carolina	551,000	27	1.40	Cement (portland), stone (crushed), cement (masonry), sand and gravel (construction), clays (kaolin).
South Dakota	233,000	38	0.59	Gold, cement (portland), sand and gravel (construction), stone (crushed), stone (dimension).
Tennessee	737,000	20	1.87	Stone (crushed), zinc, cement (portland), sand and gravel (construction), clays (ball).
Texas	1,950,000	4	4.95	Cement (portland), stone (crushed), sand and gravel (construction), lime, salt.
Utah	1,430,000	9	3.64	Copper, gold, cement (portland), sand and gravel (construction), salt.
Vermont 2/	66,900	46	0.17	Stone (dimension), stone (crushed), sand and gravel (construction), talc (crude), gemstones.
Virginia	710,000	21	1.80	Stone (crushed), cement (portland), sand and gravel (construction), lime, clays (fuller's earth).
Washington	607,000	24	1.54	Sand and gravel (construction), stone (crushed), magnesium metal, cement (portland), gold.
West Virginia	172,000	40	0.44	Stone (crushed), cement (portland), sand and gravel (industrial), lime, salt.
Wisconsin 2/	372,000	32	0.94	Sand and gravel (construction), stone (crushed), lime, sand and gravel (industrial), stone (dimension).
Wyoming	978,000	15	2.48	Soda ash, clays (bentonite), helium (grade-A), cement (portland), stone (crushed).
Undistributed	157,000	XX	0.40	
Total	39,400,000	XX	100.00	

XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Partial total; excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed."

TABLE 4
VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE KILOMETER IN 2000, BY STATE 1/

State	Area (square kilometers)	Population (thousands)	Total value (thousands)	Per capita		Per square kilometer	
				Dollars	Rank	Dollars	Rank
Alabama	134,000	4,460	$930,000	208	13	6,940	16
Alaska	1,530,000	635	1,140,000	1,790	2	745	48
Arizona	295,000	5,310	2,510,000	474	6	8,510	11
Arkansas	138,000	2,690	484,000	180	15	3,520	28
California	411,000	34,500	3,270,000	95	30	7,950	13
Colorado	270,000	4,420	592,000	134	20	2,190	41
Connecticut	13,000	3,430	112,000 2/	33	47	8,650	10
Delaware	5,290	796	12,400 2/	16	50	2,350	40
Florida	152,000	16,400	1,820,000	111	24	12,000	3
Georgia	153,000	8,380	1,620,000	193	14	10,600	6
Hawaii	16,800	1,220	92,000	75	35	5,490	24

See footnotes at end of table.

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TABLE 4--Continued
VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE KILOMETER IN 2000, BY STATE 1/

State	Area (square kilometers)	Population (thousands)	Total value (thousands)	Per capita		Per square kilometer	
				Dollars	Rank	Dollars	Rank
Idaho	216,000	1,320	$358,000	271	10	1,660	42
Illinois	146,000	12,500	913,000	73	37	6,260	23
Indiana	93,700	6,110	695,000	114	23	7,420	15
Iowa	146,000	2,920	503,000	172	16	3,450	29
Kansas	213,000	2,690	629,000	233	12	2,950	31
Kentucky	105,000	4,070	501,000	123	22	4,780	26
Louisiana	124,000	4,470	325,000	73	38	2,630	35
Maine	86,200	1,290	95,500	74	36	1,110	47
Maryland	27,100	5,380	358,000 2/	67	40	13,200	2
Massachusetts	21,500	6,380	200,000 2/	31	48	9,320	9
Michigan	152,000	9,990	1,640,000	165	17	10,800	4
Minnesota	219,000	4,970	1,460,000	293	9	6,670	20
Mississippi	124,000	2,860	149,000	52	43	1,210	44
Missouri	181,000	5,630	1,370,000	243	11	7,590	14
Montana	381,000	904	596,000	659	4	1,570	43
Nebraska	200,000	1,710	83,700 2/	49	44	418	49
Nevada	286,000	2,110	2,980,000	1,410	3	10,400	7
New Hampshire	24,000	1,260	57,100 2/	45	45	2,380	39
New Jersey	20,200	8,480	291,000 2/	34	46	14,400	1
New Mexico	315,000	1,830	786,000	430	7	2,500	38
New York	127,000	19,000	1,020,000	54	42	8,000	12
North Carolina	136,000	8,190	744,000	91	32	5,450	25
North Dakota	183,000	634	35,200	56	41	192	50
Ohio	107,000	11,400	999,000	88	33	9,330	8
Oklahoma	181,000	3,460	473,000	137	18	2,610	36
Oregon	251,000	3,470	299,000	86	34	1,190	45
Pennsylvania	117,000	12,300	1,250,000 2/	102	26	10,600	5
Rhode Island	3,140	1,060	20,300 2/	19	49	6,480	22
South Carolina	80,600	4,060	551,000	136	19	6,830	17
South Dakota	200,000	757	233,000	308	8	1,170	46
Tennessee	109,000	5,740	737,000	128	21	6,750	18
Texas	691,000	21,300	1,950,000	91	31	2,820	32
Utah	220,000	2,270	1,430,000	631	5	6,510	21
Vermont	24,900	613	66,900 2/	109	25	2,690	34
Virginia	106,000	7,190	710,000	99	28	6,730	19
Washington	176,000	5,990	607,000	101	27	3,440	30
West Virginia	62,800	1,800	172,000	96	29	2,740	33
Wisconsin	145,000	5,400	372,000 2/	69	39	2,560	37
Wyoming	253,000	494	978,000	1,980	1	3,860	27
Undistributed	XX	XX	157,000	XX	XX	XX	XX
Total or average	9,370,000 3/	284,000 3/	39,400,000	139	XX	4,200	XX

XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Partial total; excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed.
3/ Excludes Washington, DC (which has no mineral production), with an area of 179 square kilometers and a population of 572,000.

Sources: U.S. Geological Survey and U.S. Census Bureau.

TABLE 5
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1998		1999		2000	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama:						
Cement:						
Masonry	371	39,100 e/	429	47,600 e/	401	45,600 e/
Portland	4,310	353,000 e/	4,300	349,000 e/	4,340	342,000 e/
Clays, common	2,400	23,100	2,320	23,700	2,090	23,200
Gemstones	NA	76	NA	76	NA	108
Lime	1,960	119,000	1,930	114,000	1,950	121,000

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Alabama--Continued:							
Sand and gravel:							
Construction		14,400	64,100	15,500	68,900	14,500	63,700
Industrial		757	9,910	687	9,780	731	10,100
Stone:							
Crushed		48,900	383,000	49,100 r/	354,000 r/	49,100	300,000
Dimension	metric tons	W	W	7,210	2,380	W	W
Combined values of clays [bentonite, fire (1998), kaolin], iron oxide pigments (crude), salt, and values indicated by symbol W		XX	18,500	XX	20,400	XX	24,400
Total		XX	1,010,000	XX	990,000 r/	XX	930,000
Alaska:							
Gemstones		NA	11	NA	11	NA	11
Gold 3/ 4/	kilograms	18,300	174,000	16,200 r/	177,000 r/	15,600	140,000
Sand and gravel, construction		13,700	72,700	9,620	48,500	10,600	53,500
Stone, crushed		1,700 5/	9,970 5/	1,800 5/	9,900 5/	1,400	7,110
Combined values of copper, lead, silver, stone [crushed dolomite, limestone, shell, slate (1998-1999)], zinc		XX	734,000 r/	XX	880,000	XX	939,000
Total		XX	991,000 r/	XX	1,120,000 r/	XX	1,140,000
Arizona:							
Copper 3/		1,190	2,060,000	1,050	1,760,000	928	1,800,000
Gemstones		NA	2,120	NA	1,950	NA	2,920
Gold 3/	kilograms	1,840	17,400	786	7,080	W	W
Molybdenum concentrates	metric tons	16,600	W	15,700 r/	W	W	W
Sand and gravel:							
Construction		47,900	229,000	54,500	296,000	59,400	304,000
Industrial		307	3,290	268	3,720	W	W
Silver 3/	metric tons	211	37,700 r/	183	30,900	132	21,200
Stone, crushed		8,080	44,800	8,970 r/	53,900 r/	8,030	48,200
Zeolites	metric tons	(6/)	NA	(6/)	NA	(6/)	NA
Combined values of cement, clays (bentonite, common), gypsum (crude), iron oxide pigments (crude), lime, mica (1999), perlite (crude), pumice and pumicite, salt, stone (dimension sandstone), and values indicated by symbol W		XX	344,000	XX	334,000 r/	XX	333,000
Total		XX	2,740,000	XX	2,490,000 r/	XX	2,510,000
Arkansas:							
Clays, common		995	1,370	1,010	1,510	958	1,170
Gemstones		NA	912	NA	731	NA	925
Sand and gravel, construction		12,100	55,400	11,300	53,200	9,820	48,600
Silica stone 7/	metric tons	404	3,400	W	W	W	W
Stone, crushed		35,700	180,000	30,700	145,000	28,300	137,000
Combined values of bromine, cement, clays (kaolin), gypsum (crude), lime, sand and gravel (industrial), stone (dimesion limestone, marble, sandstone), tripoli, and values indicated by symbol W		XX	242,000	XX	296,000	XX	296,000
Total		XX	484,000	XX	497,000	XX	484,000
California:							
Asbestos	metric tons	5,760	W	7,190	W	5,260	W
Boron minerals		1,170	486,000	1,220	630,000	1,070	557,000
Cement:							
Masonry		410	39,600 e/	466	38,300 e/	484	43,100 e/
Portland		10,000	746,000 e/	10,300	817,000 e/	10,900	821,000 e/
Clays:							
Bentonite		29	2,700	23	2,110	21	2,160
Common		918	9,610	829	13,100	969	16,800
Gemstones		NA	1,810	NA	1,100	NA	1,500
Gold 3/	kilograms	18,700	177,000	17,500	192,000 r/	17,200	155,000
Lime		185	18,100	W	W	W	W
Rare-earth metal concentrates e/	metric tons	5,000	14,400	5,000	14,400	5,000	W
Sand and gravel:							
Construction		135,000	801,000	145,000	897,000	148,000	940,000
Industrial		1,740	40,400	1,790	43,700	1,810	45,200
Silver 3/	metric tons	11	2,020 r/	8	1,290	9	1,390

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
California--Continued:							
Stone:							
Crushed		55,100	344,000	59,400 r/	384,000 r/	59,700	373,000
Dimension	metric tons	28,500	4,710	29,400	4,930	33,300	5,790
Zeolites	do.	(6/)	NA	(6/)	NA	(6/)	NA
Combined values of clays (fire, fuller's earth, kaolin), diatomite, feldspar, gypsum (crude), iron ore [usable (1998-1999)], magnesium compounds, perlite, pumice and pumicite, pyrophyllite (1999-2000), salt, soda ash, sodium sulfate [natural (1998)], talc (1998-1999), titanium [ilmenite (1998)], and values indicated by symbol W		XX	318,000	XX	310,000	XX	308,000
Total		XX	3,000,000	XX	3,350,000 r/	XX	3,270,000
Colorado:							
Clays:							
Bentonite		W	W	1	W	W	W
Common		257	1,840	373	2,530	296	2,000
Gemstones		NA	257	NA	261	NA	277
Lime		40	1,820	40	2,380	37	2,170
Sand and gravel:							
Construction		42,900	195,000	45,200	217,000	43,900	216,000
Industrial		W	W	W	W	65	W
Stone:							
Crushed		12,000	63,800	13,200	75,500	13,000	81,900
Dimension	metric tons	14,200	3,410	14,700	3,430	W	W
Combined values of cement, clays [fire (2000)], gold, gypsum (crude), helium (grade-A), lead (1998-99), molybdenum concentrates, peat (1998), sand and gravel (industrial), silver, stone [dimension marble and sandstone (2000)], zinc (1998-1999), and values indicated by symbol W		XX	306,000	XX	282,000 r/	XX	289,000
Total		XX	572,000	XX	584,000 r/	XX	592,000
Connecticut:							
Clays, common		55	(6/)	55	183	55	183
Gemstones		NA	5	NA	6	NA	6
Sand and gravel, construction		6,380	29,200	6,510	32,400	8,010	46,900
Stone:							
Crushed		7,660	69,400	7,170	57,400	7,740	65,300
Dimension	metric tons	W	(6/)	W	(6/)	W	(6/)
Total		XX	98,700	XX	90,000	XX	112,000
Delaware:							
Gemstones		NA	1	NA	1	NA	1
Magnesium compounds	metric tons	W	(6/)	W	(6/)	W	(6/)
Sand and gravel, construction		2,560	11,500	2,100	10,800	2,330	12,400
Total		XX	11,500	XX	10,800	XX	12,400
Florida:							
Cement:							
Masonry		442	40,600 e/	494	50,900 e/	546	64,900 e/
Portland		3,470	259,000 e/	3,500	260,000 e/	3,750	285,000 e/
Clays, kaolin		W	W	35	3,830	33	3,420
Gemstones		NA	1	NA	1	NA	1
Peat		391	7,360	408	8,180	416	8,640
Sand and gravel:							
Construction		20,900	84,600	27,200	114,000	24,500	107,000
Industrial		525	6,150	509	6,370	510	6,320
Stone, crushed		81,000 5/	377,000 5/	91,700 r/	466,000 r/	93,000	495,000
Combined values of clays (common, fuller's earth), magnesium compounds, phosphate rock, staurolite, stone [crushed marl (1998)], titanium concentrates, zirocnium concentrates, and values indicated by symbol W		XX	1,030,000	XX	1,110,000	XX	848,000
Total		XX	1,810,000	XX	2,020,000	XX	1,820,000

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Georgia:							
Clays:							
Common		1,650	5,470	1,600	5,130	1,500	5,200
Fuller's earth		686	74,800	725	73,800	919	81,400
Kaolin		8,350	998,000	8,170	907,000	7,660	877,000
Gemstones		NA	8	NA	9	NA	8
Sand and gravel:							
Construction		7,130	29,500	7,200	30,100	6,940	28,700
Industrial		608	10,900	612	11,100	651	12,200
Stone:							
Crushed 5/		74,200	440,000	74,200	448,000	76,500	452,000
Dimension	metric tons	72,100	8,790	83,400	12,200	74,200	11,400
Combined values of barite, cement, feldspar, iron oxide pigments (crude), lime, mica (crude), stone (crushed marble)		XX	152,000	XX	153,000	XX	151,000
Total		XX	1,720,000	XX	1,640,000	XX	1,620,000
Hawaii:							
Cement:							
Masonry		3	329 e/	3	298 e/	3	645 e/
Portland		251	25,600 e/	254	24,700 e/	286	26,800 e/
Gemstones		NA	77	NA	55	NA	(6/)
Sand and gravel, construction		368	4,590	508	5,840	607	6,420
Stone, crushed		5,500	53,900	5,870	55,500	5,770	58,100
Total		XX	84,500	XX	86,400	XX	92,000
Idaho:							
Antimony	metric tons	242	W	450 r/	W	W	W
Gemstones		NA	321	NA	368	NA	411
Gold 3/	kilograms	W	W	W	W	2,260	20,400
Pumice and pumicite	metric tons	73,400	686	98,600	917	W	W
Sand and gravel:							
Construction		16,600	52,400	15,500	48,200	17,500	55,700
Industrial		710	8,470	711	11,200	W	W
Silver 3/	metric tons	447	79,600 r/	416	70,100	416	66,900
Stone:							
Crushed		4,180	18,400	4,090 r/	18,500 r/	3,500	14,800
Dimension	metric tons	15,900	4,710	39,300	5,510	W	W
Zeolites	do.	--	--	--	--	(6/)	NA
Combined values of cement (portland), copper, feldspar, garnet (industrial), lead, lime, molybdenum concentrates, perlite [crude, (1999-2000)], phosphate rock, stone [dimension granite, quartz, sandstone (2000)], vanadium ore (1998-1999), zinc, and values indicated by symbol W		XX	281,000	XX	266,000 r/	XX	200,000
Total		XX	446,000 r/	XX	421,000 r/	XX	358,000
Illinois:							
Cement, portland		2,690	207,000 e/	2,940	215,000 e/	2,860	218,000 e/
Clays, common		123	560	134	616	200	905
Gemstones		NA	8	NA	8	NA	8
Sand and gravel:							
Construction		34,100	150,000	34,100	147,000	30,300	132,000
Industrial		4,580	71,100	4,460	71,100	4,430	71,600
Stone, crushed 5/		72,100	371,000	76,900 r/	388,000 r/	76,000	394,000
Combined values of clays (fuller's earth), lime, peat, stone (crushed sandstone), tripoli		XX	75,400	XX	77,000 r/	XX	96,200
Total		XX	875,000	XX	899,000 r/	XX	913,000
Indiana:							
Cement:							
Masonry		W	W	W	W	444	46,800 e/
Portland		2,500	176,000 e/	2,510	178,000 e/	2,630	179,000 e/
Clays, common		681	1,330	752	1,480	639	1,560
Gemstones		NA	3	NA	3	NA	3
Sand and gravel:							
Construction		24,000	101,000	29,500	126,000	27,900	121,000
Industrial		W	W	175	1,860	W	W

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Indiana--Continued:							
Stone:							
Crushed 5/		61,800	283,000	58,800 r/	270,000 r/	55,400	253,000
Dimension	metric tons	220,000	28,200	255,000	33,500	235,000	32,400
Combined values of clays [ball (1998)], gypsum (crude), lime, peat, stone [crushed slate (1998)], and values indicated by symbol W		XX	102,000	XX	106,000	XX	61,400
Total		XX	691,000	XX	716,000 r/	XX	695,000
Iowa:							
Cement, portland		2,610	211,000 e/	W	W	W	W
Clays, common		301	1,040	302	1,040	306	1,060
Gemstones		NA	4	NA	2	NA	2
Sand and gravel:							
Construction		13,500	58,500	13,500	60,600	12,300	54,100
Industrial		W	W	W	W	29	W
Stone, crushed		41,800	219,000	40,200 r/	203,000 r/	40,200	209,000
Combined values of cement (masonry), gypsum (crude), lime, peat, and values indicated by symbol W		XX	27,700	XX	216,000	XX	239,000
Total		XX	518,000	XX	481,000 r/	XX	503,000
Kansas:							
Cement, portland		1,800	138,000 e/	1,970	149,000 e/	1,980	155,000 e/
Clays, common		585	2,510	592	2,770	594	3,970
Gemstones		NA	29	NA	21	NA	12
Helium, Grade-A	million cubic meters	56	110,000	61	121,000	77	153,000
Salt		3,090	120,000	2,780	115,000	2,770	114,000
Sand and gravel, construction		10,800	31,400	10,800	31,300	10,000	28,200
Stone:							
Crushed		21,800	115,000	23,700 r/	116,000	23,300	113,000
Dimension	metric tons	15,800	1,240	16,100	1,640	14,100	1,890
Combined values of cement (masonry), clays (fuller's earth), gypsum (crude), helium (crude), pumice and pumicite, sand and gravel (industrial)		XX	31,400	XX	63,700	XX	59,800
Total		XX	551,000	XX	601,000 r/	XX	629,000
Kentucky:							
Clays:							
Common		872	3,930	892	3,790	1,000	4,190
Fire		W	W	W	W	10	35
Gemstones		NA	263	NA	292	NA	47
Sand and gravel, construction		8,100	27,500	9,620	32,400	11,000	36,000
Stone, crushed		58,600 5/	285,000 5/	59,800 r/	308,000 r/	55,600	296,000
Combined values of cement, clays (ball), lime, stone [crushed sandstone (1998)]		XX	175,000	XX	158,000	XX	164,000
Total		XX	492,000	XX	502,000 r/	XX	501,000
Louisiana:							
Clays, common		620	1,530 r/	626	1,540 r/	636	1,530
Gemstones		NA	5	NA	7	NA	6
Salt		14,900	173,000	16,500	193,000	13,400	124,000
Sand and gravel:							
Construction		11,400	53,800	16,500	81,700	14,900	76,900
Industrial		623	12,100	636	10,400	648	12,300
Combined values of gypsum (crude), lime, stone [crushed limestone and sandstone (1999-2000), crushed sandstone (1998)], sulfur (Frasch)		XX	96,300	XX	116,000 r/	XX	110,000
Total		XX	337,000 r/	XX	402,000 r/	XX	325,000
Maine:							
Clays, common		W	W	W	W	49 e/	125 e/
Gemstones		NA	228	NA	229	NA	239
Sand and gravel, construction		7,640	33,400	8,570	40,300	9,670	37,600
Stone, crushed		4,120	23,000	3,550 r/	21,200 r/	3,650	21,100
Combined values of cement, peat, stone (dimension granite), and values indicated by symbol W		XX	35,000	XX	38,400	XX	36,500
Total		XX	91,600	XX	100,000 r/	XX	95,500

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Maryland:						
Cement:						
Masonry	W	W	110	10,000 e/	78	7,140 e/
Portland	1,760	123,000 e/	1,730	124,000 e/	1,760	125,000 e/
Clays, common	339	1,380	335	1,380	271	982
Gemstones	NA	1	NA	1	NA	1
Sand and gravel, construction	10,400	60,500	8,970	56,500	13,100	84,700
Stone:						
Crushed 5/	24,300	141,000	22,200	121,000	24,500	137,000
Dimension metric tons	23,100	2,730	26,000	3,160	28,700	3,560
Combined values of sand and gravel (industrial), stone [crushed marble and traprock (1998), crushed marble, shell, traprock (1999-2000)], and value indicated by symbol W	XX	23,700	XX	(6/)	XX	(6/)
Total	XX	352,000	XX	316,000	XX	358,000
Massachusetts:						
Clays, common	W	W	W	W	36 e/	321 e/
Gemstones	NA	1	NA	1	NA	1
Sand and gravel, construction	14,000	78,000	12,700	75,200	13,200	80,100
Stone:						
Crushed	12,800	96,900	11,600	89,900	13,400	103,000
Dimension metric tons	85,800	17,600	70,400	16,900	69,600	16,800
Combined values of lime, sand and gravel [industrial (1998-1999)] and values indicated by symbol W	XX	12,000	XX	10,800	XX	(6/)
Total	XX	204,000	XX	193,000	XX	200,000
Michigan:						
Cement:						
Masonry	294	28,000 e/	283	28,100 e/	296	28,900 e/
Portland	5,710	435,000 e/	5,810	439,000 e/	5,790	450,000 e/
Clays, common	644	2,920	615	3,550	594	3,210
Gemstones	NA	1	NA	1	NA	1
Gypsum, crude	1,830	15,000	2,170	15,700	1,980	19,800
Lime	761	40,300	781	43,900	W	W
Peat	190	5,500	195	4,520	207	5,750
Sand and gravel:						
Construction	66,900	245,000	70,200	245,000	75,600	269,000
Industrial	2,390	25,700	2,550	28,100	2,520	27,800
Stone, crushed 5/	43,700	167,000	41,200 r/	140,000 r/	42,200	148,000
Combined values of bromine, iron ore (usable), iron oxide pigments (crude), magnesium compounds, potash, salt, stone (crushed marl and miscellaneous, dimension dolomite and sandstone), and value indicated by symbol W	XX	706,000	XX	625,000	XX	691,000
Total	XX	1,670,000	XX	1,570,000 r/	XX	1,640,000
Minnesota:						
Clays, common	W	W	W	W	14	15
Gemstones	NA	5	NA	6	NA	6
Iron ore, usable	47,200	1,470,000	43,800 r/	1,150,000	46,700	1,180,000
Peat	30	1,630	W	W	75	5,100
Sand and gravel, construction	39,400	154,000	37,300	142,000	39,500	158,000
Stone:						
Crushed	13,600 5/	71,500 5/	13,100 r/	62,700 r/	12,400	68,100
Dimension metric tons	48,100	18,800	42,700	20,700	W	W
Combined values of lime, sand and gravel (industrial), stone [crushed sandstone (1998-1999), dimension garnite and limestone (2000)], and values indicated by symbol W	XX	23,000	XX	35,200	XX	44,100
Total	XX	1,740,000	XX	1,410,000 r/	XX	1,460,000
Mississippi:						
Clays:						
Common	502	3,410	497	3,390	484	2,200
Fuller's earth	372	30,400	377	29,400	371	30,100
Gemstones	NA	1	NA	1	NA	1
Sand and gravel, construction	13,300	64,400	12,100	58,900	10,700	41,700
Stone, crushed 5/	789	2,790	1,760	15,900	2,530	23,700

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998		1999		2000	
		Quantity	Value	Quantity	Value	Quantity	Value
Mississippi--Continued:							
Combined values of cement (portland), clays (ball, bentonite), sand and gravel (industrial), stone (crushed marl)		XX	58,400	XX	52,300	XX	51,700
Total		XX	159,000	XX	160,000	XX	149,000
Missouri:							
Cement, portland		4,570	323,000 e/	4,910	354,000 e/	4,880	372,000 e/
Clays:							
Common		1,030	4,440	1,080	4,180	1,050	3,240
Fire		288	4,220	293	3,980	351	4,630
Copper 3/		5	9,090	W	W	W	W
Sand and gravel, construction		9,470	39,300	12,400	50,300	11,700	60,900
Stone, crushed		68,400	356,000	72,600 r/	346,000 r/	75,500	399,000
Combined values of cement (masonry), clays (fuller's earth), gemstones, iron ore [usable (1998-1999)], iron oxide pigments (crude), lead, lime, sand and gravel (industrial), silver, stone (dimension granite), zinc, and values indicated by symbol W		XX	608,000 r/	XX	585,000 r/	XX	531,000
Total		XX	1,340,000 r/	XX	1,340,000 r/	XX	1,370,000
Montana:							
Gemstones		NA	453	NA	294	NA	267
Gold 3/	kilograms	8,200	77,900	7,540 r/	82,800 r/	9,310	83,800
Lead 3/	metric tons	7,310	7,300	7,950	7,660	W	W
Palladium 3/	kilograms	10,600	98,600	9,800	114,000	10,300	228,000
Platinum 3/	do.	3,240	39,000 r/	2,920	35,600	3,110	69,200
Sand and gravel, construction		8,550	34,900	12,000	50,700	9,950	40,600
Stone:							
Crushed		3,880	15,100	3,480 r/	13,400 r/	3,070	12,600
Dimension	metric tons	W	W	9,500	1,440	W	W
Zinc 3/	do.	24,900	28,200	22,200	26,100	16,600	21,500
Combined values of cement [masonry (1998, 2000), portland], clays (bentonite, common), copper, garnet (industrial), iron ore [usable (1998-1999)], lime, molybdenum concentrates, peat, silver, talc, and value indicated by symbol W		XX	203,000 r/	XX	183,000 r/	XX	140,000
Total		XX	504,000 r/	XX	515,000 r/	XX	596,000
Nebraska:							
Cement:							
Masonry		W	(6/)	W	(6/)	W	(6/)
Portland		W	(6/)	W	(6/)	W	(6/)
Clays, common		134	345	133	(6/)	133	338
Gemstones		NA	3	NA	3	NA	3
Lime		19	1,580	18	1,510	20	1,690
Sand and gravel:							
Construction		13,800	47,000	12,000	40,800	11,700	39,200
Industrial		W	(6/)	W	(6/)	W	(6/)
Stone, crushed		7,490	49,800	7,090	44,500	6,590	42,400
Total		XX	98,700	XX	86,800	XX	83,700
Nevada:							
Clays:							
Bentonite		W	W	6	W	6	804
Fuller's earth		W	W	25	3,580	28	3,870
Gemstones		NA	159	NA	205	NA	W
Gold 3/	kilograms	273,000	2,590,000	256,000 r/	2,810,000 r/	268,000	2,410,000
Sand and gravel:							
Construction		26,400	114,000	31,700	142,000	36,800	172,000
Industrial		W	W	W	W	609	W
Silver 3/	metric tons	670	119,000 r/	597	101,000	633	102,000
Stone, crushed		6,320	34,000	7,090	37,900	7,640	37,300
Zeolites	metric tons	(6/)	NA	--	--	(6/)	NA

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Nevada--Continued:							
Combined values of barite, brucite, cement (portland), clays (kaolin), copper, diatomite, gypsum (crude), iron ore [usable (1998-1999)], lead (2000), lime, lithium, magnesite, mercury (1999-2000), perlite (crude), salt, sand and gravel (industrial), and values indicated by symbol W		XX	320,000	XX	286,000	XX	250,000
Total		XX	3,180,000 r/	XX	3,380,000 r/	XX	2,980,000
New Hampshire:							
Gemstones		NA	6	NA	6	NA	6
Sand and gravel, construction		8,590	40,000	7,950	36,700	8,660	41,400
Stone, crushed 3/		4,190	27,500	4,290	19,700	3,740	15,700
Combined values of stone (crushed sandstone and dimension dimension granite)		XX	(6/)	XX	(6/)	XX	(6/)
Total		XX	67,600	XX	56,400	XX	57,100
New Jersey:							
Clays, common		W	W	W	W	W	130
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		16,600	90,800	16,500	91,500	16,300	85,000
Industrial		1,800	34,400	1,580	32,100	1,690	35,700
Stone, crushed		23,900	161,000	24,500	160,000	24,900	170,000
Combined values of greensand marl and peat and values indicated by symbol W		XX	3,080	XX	3,200	XX	(6/)
Total		XX	290,000	XX	287,000	XX	291,000
New Mexico:							
Clays:							
Common		33	173	W	W	34	256
Fire		1	17	1	W	--	--
Copper 3/		252	438,000	197	330,000	195	380,000
Gemstones		NA	W	NA	13	NA	27
Sand and gravel, construction		11,100	53,300	10,600	53,000	13,400	66,800
Stone:							
Crushed		4,940 5/	21,000 5/	3,710 r/	22,200	3,690	22,400
Dimension	metric tons	W	W	17,900	2,320	W	W
Zeolites	do.	(6/)	NA	(6/)	NA	(6/)	NA
Combined values of cement, gold, gypsum (crude), iron ore (usable), lime (2000), mica (crude), molybdenum concentrates, perlite (crude), potash, pumice and pumicite, salt, sand and gravel [industrial (1999-2000)], silver, stone [crushed sandstone and traprock (1998), dimension miscellaneous (1998), dimension sandstone and miscellaneous (2000)], and values indicated by symbol W		XX	341,000	XX	311,000 r/	XX	317,000
Total		XX	853,000	XX	719,000 r/	XX	786,000
New York:							
Cement, portland		W	W	W	W	2,700	211,000 e/
Clays, common		622	16,100	W	W	630	7,820
Gemstones		NA	64	NA	68	NA	64
Salt		4,120	198,000	4,220	209,000	5,440	218,000
Sand and gravel, construction		32,100	161,000	29,900	152,000	29,700	154,000
Stone:							
Crushed		47,200	279,000	46,200 r/	266,000 r/	48,800	304,000
Dimension	metric tons	52,900	8,870	49,300	8,940	62,200	5,780
Combined values of cement (masonry), garnet (industrial), gypsum (crude), lead, peat, sand and gravel (industrial), silver (1998-1999), talc, wollastonite, zinc, and values indicated by symbol W		XX	309,000	XX	358,000	XX	117,000
Total		XX	972,000	XX	994,000 r/	XX	1,020,000
North Carolina:							
Clays, common		2,380	11,600	2,430	18,700	2,430	18,600
Feldspar	metric tons	381,000	16,800	381,000	16,100	W	W
Gemstones		NA	968	NA	2,860	NA	372

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
North Carolina--Continued:							
Sand and gravel:							
Construction		10,900	58,000	11,600	62,900	12,000	59,100
Industrial		1,440	24,100	1,470	27,300	1,480	28,300
Stone:							
Crushed		69,700	480,000	67,000	459,000	69,500	478,000
Dimension	metric tons	26,200	12,500	54,700	17,700	40,500	16,800
Combined values of clays (kaolin), lithium (1998), mica (crude), olivine, peat, phosphate rock, pyrophyllite, and value indicated by symbol W		XX	146,000	XX	138,000	XX	143,000
Total		XX	750,000	XX	742,000	XX	744,000
North Dakota:							
Clays, common		42	W	54	W	79	W
Gemstones		NA	3	NA	3	NA	3
Lime		W	W	W	W	176	7,010
Sand and gravel:							
Construction		10,700	30,400	11,700	33,000	10,600	27,800
Industrial		W	W	W	W	1	W
Combined values of peat (1998-99), sand and gravel (industrial), stone [crushed limestone, volcanic cinder, miscellaneous (1999-2000), crushed volcanic cinder and miscellaneous (1998)], and values indicated by symbol W		XX	7,860	XX	7,580	XX	410
Total		XX	38,300	XX	40,600	XX	35,200
Ohio:							
Cement:							
Masonry		W	W	W	W	92	11,000 e/
Portland		W	W	1,130	90,800 e/	1,030	83,300 e/
Clays:							
Common		1,530	7,290	1,710	8,170	1,370	7,380
Fire		62	2,810	W	W	W	W
Gemstones		NA	3	NA	3	NA	3
Lime		1,870	109,000	1,820	105,000	1,850	106,000
Sand and gravel:							
Construction		52,600	255,000	52,000	257,000	51,200	256,000
Industrial		1,110	27,700	1,150	30,700	1,200	32,800
Stone:							
Crushed		74,900 r/	348,000 r/	73,200	328,000	73,600	327,000
Dimension	metric tons	24,100	2,360	25,600	2,390	34,500	3,050
Combined values of gypsum (crude), peat, salt, silica stone 7/ (1998), and values indicated by symbol W		XX	276,000	XX	220,000	XX	172,000
Total		XX	1,030,000	XX	1,040,000	XX	999,000
Oklahoma:							
Cement:							
Masonry		96	7,140 e/	W	W	109	9,990 e/
Portland		1,830	132,000 e/	W	W	W	W
Clays, common		658	4,450	757	2,050	757	2,060
Gemstones		NA	53	NA	268	NA	197
Gypsum, crude		3,020	19,500	3,510	20,100	2,830	23,500
Iodine, crude	metric tons	1,490	22,700	1,620	23,800	1,470	21,500
Sand and gravel:							
Construction		9,000	35,900	10,200	41,200	9,210	35,500
Industrial		1,380	29,600	1,470	30,900	1,480	30,700
Stone:							
Crushed		38,500	152,000	36,200 r/	145,000	39,300	168,000
Dimension	metric tons	3,480	635	3,480	635	5,910	1,530
Combined values of feldspar, helium, lime, salt, tripoli, and values indicated by symbol W		XX	55,600	XX	177,000	XX	180,000
Total		XX	460,000	XX	441,000	XX	473,000
Oregon:							
Clays, common		177	W	240	77	227	632
Gemstones		NA	1,500	NA	949	NA	856
Sand and gravel, construction		18,600	99,200	16,900	105,000	16,500	97,000

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Oregon--Continued:							
Stone, crushed		23,200	118,000	23,300 r/	111,000 r/	20,800	98,900
Zeolites	metric tons	(6/)	NA	(6/)	NA	(6/)	NA
Combine value of cement (portland), clays (bentonite), diatomite, emery, lime, perlite (crude), pumice and pumicite, talc, and value indicated by symbol W		XX	82,400	XX	101,000	XX	102,000
Total		XX	301,000	XX	318,000 r/	XX	299,000
Pennsylvania:							
Cement:							
Masonry		319	31,100 e/	330	35,800 e/	324	33,700 e/
Portland		6,740	457,000 e/	6,690	479,000 e/	6,640	475,000 e/
Clays, common		886	2,270	816	1,760	840	1,870
Gemstones		NA	1	NA	1	NA	1
Lime		1,390	97,800	1,340	94,300	1,350	93,900
Peat		6	154	6	185	6	183
Sand and gravel, construction		19,200	116,000	18,600	115,000	17,900	110,000
Stone:							
Crushed		94,500	504,000	91,300 r/	485,000 r/	97,900	520,000
Dimension	metric tons	45,200	9,480	50,800	12,600	49,500	12,100
Combined values of clays [kaolin, (1998)], sand and gravel (industrial), tripoli		XX	11,800	XX	(6/)	XX	(6/)
Total		XX	1,230,000	XX	1,220,000 r/	XX	1,250,000
Rhode Island:							
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		1,390	11,100	1,310	9,900	1,240	9,780
Industrial		W	(6/)	W	(6/)	104	(6/)
Stone, crushed		2,240	14,200	2,070	12,200	1,860	10,600
Total		XX	25,300	XX	22,100	XX	20,300
South Carolina:							
Cement:							
Masonry		374	43,700 e/	421	49,400 e/	411	45,500 e/
Portland		2,640	210,000 e/	2,610	205,000 e/	2,910	210,000 e/
Clays:							
Common		1,220	3,950	1,130	4,930	890	2,790
Fire		36	38	35	45	40	50
Kaolin		395	22,000	408	15,700	397	21,900
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		9,690	35,900	9,660	38,200	10,300	40,800
Industrial		881	20,700	769	18,400	755	18,600
Stone:							
Crushed		28,000	182,000	28,600 r/	189,000 r/	29,400	189,000
Dimension	metric tons	12,900	1,150	9,230	855	W	W
Combined values of gold (1998-1999), lime (1999-2000), mica (crude), silver (1998-1999), vermiculite, and value indicated by symbol W		XX	42,600	XX	47,800 r/	XX	21,900
Total		XX	562,000	XX	569,000 r/	XX	551,000
South Dakota:							
Clays, common		188	W	183	W	191	W
Gemstones		NA	W	NA	5	NA	W
Gold 3/	kilograms	12,100	115,000	10,300 r/	113,000 r/	8,230	74,200
Sand and gravel, construction		10,100	35,600	12,400	45,600	12,800	46,500
Silver 3/	metric tons	2	348 r/	W	W	1	227
Stone, crushed		5,720	24,600	6,020	26,500	5,460	25,500
Combined values of cement, feldspar, gypsum (crude), iron ore (usable), lime, mica (crude), stone (dimension granite), and values indicated by symbol W		XX	83,500 r/	XX	92,600 r/	XX	86,400
Total		XX	259,000 r/	XX	277,000 r/	XX	233,000
Tennessee:							
Clays, ball		712	30,100	725	30,100	685	29,300

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Tennessee--Continued:							
Sand and gravel:							
Construction		9,410	49,800	9,640	53,100	8,760	47,000
Industrial		999	17,100	W	W	W	W
Stone, crushed		63,600	370,000	63,100	382,000	62,100	371,000
Combined values of barite, cement, clays [common, fuller's earth, kaolin], copper (1998-1999), gemstones, lead, lime, salt, silver (1998-1999), stone (dimension marble), zinc, and values indicated by symbol W		XX	237,000	XX	261,000 r/	XX	290,000
Total		XX	705,000	XX	726,000 r/	XX	737,000
Texas:							
Cement:							
Masonry		216	20,500 e/	261	29,400 e/	268	28,800 e/
Portland		8,430	621,000 e/	8,680	659,000 e/	9,270	683,000 e/
Clays, common		2,120	10,100	2,100	9,890	2,210	9,460
Gemstones		NA	11	NA	11	NA	11
Gypsum, crude		2,260	15,500	2,230	15,700	1,760	8,980
Lime		1,620	101,000	1,670 r/	111,000 r/	1,600	105,000
Salt		9,420	83,900	10,200	97,500	10,800	104,000
Sand and gravel:							
Construction		74,600	354,000	77,100	373,000	80,800	408,000
Industrial		1,760	38,500	1,620	37,100	1,750	45,200
Stone:							
Crushed		100,000 r/	401,000 r/	108,000 r/	447,000 r/	121,000	496,000
Dimension	metric tons	40,900	16,700	82,500	24,200	84,700	11,500
Talc	do.	245,000 r/	5,230 r/	220,000	5,000	230,000	4,660
Zeolites	do.	(6/)	NA	(6/)	NA	(6/)	NA
Combined values of brucite (2000), clays (ball, bentonite, fuller's earth, kaolin), helium, magnesium compounds (1998), magnesium metal (1998), sulfur [Frasch (1998-1999)]		XX	158,000	XX	58,400	XX	44,900
Total		XX	1,830,000 r/	XX	1,870,000 r/	XX	1,950,000
Utah:							
Beryllium concentrates	metric tons	6,080	7	5,070	6	4,510	5
Clays, common		298	4,760	327	4,600	335	5,380
Gemstones		NA	W	NA	1,040	NA	1,030
Salt		1,770	68,100	1,890	92,000	2,110	108,000
Sand and gravel, construction		46,300	140,000	39,500	125,000	30,900	109,000
Stone, crushed		6,970 r/	35,900 r/	8,780	45,300	8,520	42,100
Combined values of cement (portland), clays (bentonite), copper, gold, gypsum (crude), helium (grade-A), lime, magnesium compounds, magnesium metal, mercury (1998), molybdenum concentrates, perlite (crude), phosphate rock, potash, silver, stone [dimension quartz and sandston (1999-2000)], and value indicated by symbol W		XX	1,090,000	XX	1,060,000 r/	XX	1,170,000
Total		XX	1,340,000	XX	1,330,000 r/	XX	1,430,000
Vermont:							
Gemstones		NA	1	NA	1	NA	1
Sand and gravel, construction		4,940	21,200	4,430	18,800	4,140	18,800
Stone:							
Crushed		5,590	28,500	5,400	22,800	5,210	21,500
Dimension	metric tons	93,300	24,500	98,600	25,600	103,000	26,600
Talc	do.	W	(6/)	W	(6/)	W	(6/)
Total		XX	74,200	XX	67,200	XX	66,900
Virginia:							
Clays, common		872	3,310	881	3,240	1,010	2,380
Kyanite e/		90	13,200	90	12,700	90	13,400
Lime		859	51,700	W	W	W	W
Sand and gravel, construction		11,900	54,800	11,300	53,800	12,100	63,200
Stone:							
Crushed		65,900	390,000	66,400	389,000	68,800	424,000
Dimension	metric tons	5,430	600	5,640	624	W	W
Titanium, ilmenite	do.	W	W	139,000	13,900	139,000	13,900

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Virginia--Continued:							
Combined values of cement (portland), clays (fuller's earth), feldspar, gypsum [crude (1998-1999)], iron oxide pigments (crude), mica [crude (2000)], sand and gravel (industrial), vermiculite, zirconium concentrates, and values indicated by symbol W		XX	122,000	XX	176,000	XX	193,000
Total		XX	636,000	XX	650,000	XX	710,000
Washington:							
Cement, portland		1,200	95,500 e/	W	W	W	W
Clays, common		178	W	110	W	116	425
Gemstones		NA	24	NA	34	NA	37
Gold 3/	kilograms	3,540	33,600	3,250	29,200	2,930	26,400
Sand and gravel, construction		45,700	214,000	43,800	227,000	41,800	221,000
Silver 3/	metric tons	1	111 r/	W	W	2	250
Stone, crushed		19,400	111,000	19,300 r/	146,000	18,900	122,000
Combined values of cement [masonry (1998)], diatomite, gypsum [crude (1999-2000)], lime, magnesium metal, olivine, peat, sand and gravel (industrial), stone (dimension miscellaneous), and values indicated by symbol W		XX	156,000	XX	260,000	XX	237,000
Total		XX	609,000	XX	662,000	XX	607,000
West Virginia:							
Clays, common		231	515	336	813	199	560
Gemstones		NA	1	NA	1	NA	1
Sand and gravel, construction		1,650	8,050	1,850	9,030	1,980	9,800
Stone, crushed 5/		12,300	68,100	12,500 r/	56,500 r/	12,100	52,800
Combined values of cement, lime, peat, salt, sand and gravel (industrial), stone (crushed dolomite and dimension sandstone)		XX	93,000	XX	104,000	XX	109,000
Total		XX	170,000	XX	171,000 r/	XX	172,000
Wisconsin:							
Gemstones		NA	5	NA	6	NA	6
Lime		582	35,400	618	37,000	619	37,000
Peat		W	(6/)	W	(6/)	W	(6/)
Sand and gravel:							
Construction		34,700	116,000	35,700	128,000	39,600	150,000
Industrial		1,750	34,500	1,730	32,000	1,790	36,200
Silica stone 7/	metric tons	W	(6/)	W	(6/)	W	(6/)
Stone:							
Crushed		31,200	127,000	33,800 r/	135,000 r/	33,700	137,000
Dimension	metric tons	77,100	10,800	85,500	13,400	93,100	11,700
Total		XX	323,000	XX	345,000 r/	XX	372,000
Wyoming:							
Clays, bentonite		3,150	145,000	3,370	146,000	3,080	126,000
Gemstones		NA	14	NA	12	NA	12
Sand and gravel, construction		4,770	18,100	4,410	17,200	6,340	23,800
Stone, crushed		5,580	31,600	6,970	27,600	6,250	26,100
Zeolites	metric tons	(6/)	NA	--	--	--	--
Combined values of cement (portland), clays (common), gypsum (crude), helium (grade-A), lime, soda ash		XX	879,000	XX	814,000	XX	802,000
Total		XX	1,070,000	XX	1,000,000	XX	978,000
Undistributed:							
Connecticut, Delaware, Hawaii (2000), Maryland (1999-2000), Massachusetts (2000), Nebraska (1998-2000), New Hampshire, New Jersey (2000), Pennsylvania (1999-2000), Rhode Islaand, Vermont, Wisconsin, undistributed (1998, 2000)		XX	98,200	XX	64,300	XX	157,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data, value included with "Combined value." XX Not applicable.
-- Zero.
1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Recoverable content of ores, etc.
4/ Data collected by State.
5/ Excludes certain stones; kind and value included with "Combined value."
6/ Withheld to avoid disclosing company proprietary data, values included with "Undistributed."
7/ Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

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TABLE 6
NONFUEL RAW MINERAL PRODUCTION IN THE COMMONWEALTH OF PUERTO RICO AND ISLANDS ADMINISTERED BY THE UNITED STATES 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1998 Quantity	1998 Value	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Puerto Rico:							
Cement, portland	metric tons	1,590	W	W	W	1,660	W
Clays, common		W	W	159	W	141	458
Lime		37	4,800	27	3,770	16	2,750
Salt		45	1,500	45	1,500	45	1,500
Stone, crushed		12,700	58,600	13,200	56,800	10,800	51,000
Combined values of sand and gravel (industrial), and stone (dimension marble), and values indicated by symbol W		XX	156,000	XX	178,000	XX	193,000
Total		XX	221,000	XX	240,000	XX	249,000
Administered Islands:							
American Samoa, stone, crushed		W	(3/)	W	(3/)	--	--
Guam, stone, crushed		1,850	14,100	1,740	11,800	121	856
Virgin Islands, stone, crushed limestone and traprock		W	(3/)	W	(3/)	W	(3/)
Total		XX	14,100	XX	11,800	XX	856

W Withheld to avoid disclosing company proprietary data; value included with "Combined values" data. XX Not applicable. -- Zero.
1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Withheld to avoid disclosing company proprietary data.

TABLE 7
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	1,640,000	3,530,000	1,760,000	3,880,000
Manufactures	do.	106,000	374,000	100,000	388,000
Antimony:					
Metal, alloys, waste and scrap	do.	473	1,810	1,080	2,820
Oxide, antimony content	do.	3,190	10,000	6,040	14,200
Arsenic metal	do.	1,350	4,650	41	5,620
Bauxite and alumina:					
Alumina, calcined equivalent		1,230	435,000	1,090	452,000
Bauxite:					
Calcined, refractory and other grade		34	6,570	9	1,800
Crude and dried		115	10,100	133	8,950
Speciality aluminum compounds, sulfate, chloride, fluoride-based	metric tons	38,800	29,300	32,800	29,200
Beryllium, alloys, wrought or unwrought, and waste and scrap	kilograms	39,600	6,770	33,900	5,410
Bismuth, metal, alloys, and waste and scrap, bismuth content	do.	257,000	2,000	491,000	4,840
Cadmium:					
Metal, includes alloys and scrap	do.	20,400	523	312,000	1,140
Sulfide, gross weight	do.	107,000	28	1,110,000	607
Chromium:					
Chemicals	metric tons	41,800	55,600	37,200	60,400
Chromite ore and concentrate	do.	110,000	8,580	138,000	10,200
Metals, alloys, ferroalloys	do.	8,160	22,100	39,000	34,300
Pigments and preparations	do.	1,470	6,200	1,040	5,340
Cobalt:					
Metal:					
Unwrought, powders, waste and scrap, mattes, other intermediate products of metallurgy	do.	1,100	34,000	1,520	54,500
Wrought and cobalt articles	do.	546	26,400	971	37,800
Oxides and hydroxides	do.	521	8,140	1,320	11,700
Other forms, acetates and chlorides	do.	307	3,100	676	3,650

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Columbium (niobium) and tantalum:					
Columbium:					
Ferrocolumbium	metric tons	166	1,110	60	526
Ores and concentrates	do.	12	566	55	830
Tantalum:					
Ores and concentrates, includes synthetic	do.	317	7,280	354	11,600
Unwrought, alloys, metal, powders, waste and scrap	do.	418	65,000	429	99,200
Wrought	do.	132	43,500	139	47,500
Copper:					
Scrap, alloyed and unalloyed	do.	315,000	366,000	486,000	536,000
Semimanufactures	do.	150,000 r/	473,000 r/	188,000	638,000
Unmanufactured, does not include unalloyed scrap, copper content	do.	146,000 r/	204,000 r/	255,000	398,000
Ferroalloys not listed elsewhere:					
Ferrophosphorous	do.	1,100	699	4,510	3,110
Ferrotitanium and ferrosilicon-titanium	do.	1,210	2,650	1,090	2,990
Ferrozirconium	do.	51	155	213	482
Ferroalloys, other	do.	3,370	6,030	3,020	6,380
Gold:					
Bullion, refined	kilograms	435,000	3,880,000	440,000	4,030,000
Compounds	do.	561,000	14,100	1,390,000	15,300
Doré and precipitates	do.	87,300	778,000	106,000	924,000
Metal powder	do.	270	2,800	1,130	10,700
Ores and concentrates	do.	117	1,180	745	9,680
Waste and scrap	do.	40,000	302,000	64,100	700,000
Indium e/	metric tons	25	5,500	15	3,300
Iron and steel:					
Cast iron and steel products		203	447,000	202	445,000 e/
Fabricated steel products		1,120	3,640,000	1,050	3,410,000 e/
Steel mill products		4,920	4,260,000	5,920	5,120,000 e/
Iron and steel scrap:					
Direct-reduced iron, steelmaking grade		3	302	2	241
Ferrous, includes tinplate and terplate, excludes used rails for rerolling and other uses, ships, boats, other vessels for scrapping		5,520	738,000	5,760	1,000,000
Pig iron, all grades		83	11,100	72	9,620
Ships, boats, other vessels for scrapping		7	2,610	11	153
Used rails for rerolling and other uses, includes mixed (new plus used) rails		34 r/	14,300	40	15,600
Iron ore		6,120	243,000	6,150	246,000
Lead, lead content:					
Ash and residues	metric tons	1,430	2,000	11,300	18,400
Base bullion	do.	64,100	76,200	32,100	75,300
Ore and concentrate	do.	93,500	33,400	117,000	42,600
Scrap, gross weight	do.	117,000	22,000	71,600	13,200
Unwrought and alloys	do.	23,400	17,700	21,400	23,800
Wrought and alloys	do.	13,900	38,500	27,200	57,600
Magnesium:					
Alloys, gross weight	do.	2,760	11,300	6,020	23,300
Metal	do.	4,790	14,600	7,300	20,200
Powder, sheets, tubing, ribbons, wire, other forms, gross weight	do.	4,990	20,200	4,060	24,000
Waste and scrap	do.	16,500	46,500	6,400	17,500
Manganese:					
Ferromanganese, all grades	do.	11,600	6,510	7,950	5,290
Metal, including alloys, waste and scrap	do.	3,540	7,940	2,220	5,020
Ore and concentrates with 20% or more manganese	do.	4,170	651	10,000	2,200
Silicomanganese	do.	3,700	2,180	1,870	1,200
Mercury	do.	181	1,120	178	2,040
Molybdenum, molybdenum content:					
Ferromolybdenum	do.	1,510	12,400	1,230	9,940
Ore and concentrates, including roasted and other	do.	27,900	129,000	23,600	104,000
Oxides and hydroxides, gross weight	do.	1,130	8,510	1,190	8,560
Molybdates, all	do.	1,300	7,050	1,080	7,530
Powder, gross weight	do.	362	7,540	300	6,940

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Molybdenum, molybdenum content--Continued:					
Unwrought, gross weight	metric tons	167	2,430	228	3,550
Wire, gross weight	do.	200	13,900	150	9,300
Wrought, gross weight	do.	147	8,050	185	9,610
Nickel, nickel content:					
Alloyed, gross weight	do.	27,300	371,000	28,700	433,000
Unwrought:					
Primary and chemicals, includes carbonate	do.	7,440	140,000	8,150	124,000
Secondary	do.	31,400	192,000	49,900	371,000
Wrought	do.	922	11,500	1,410	23,700
Platinum-group metals, metal content:					
Iridium, osmium, ruthenium	kilograms	851	11,200	1,480	17,200
Palladium	do.	43,800 r/	271,000 r/	58,600	518,000
Platinum	do.	27,100	520,000	32,400	505,000
Rhodium	do.	114	5,310	797	50,800
Rare-earths, estimated REO content:					
Cerium compounds	do.	3,960,000	18,400	4,050,000	19,000
Compounds	do.	1,690,000	19,600	1,760,000	24,700
Ferrocerium and other pyrophoric alloys	do.	2,360,000	10,700	2,300,000	7,620
Metals, including scandium and yttrium	do.	1,600,000	5,280	1,650,000	9,830
Selenium, metal, waste and scrap, selenium content	do.	233,000	1,900	82,100	583
Silicon, gross weight:					
Ferrosilicon	metric tons	46,600	40,100	43,300	41,900
Metal	do.	37,700	281,000	18,900	334,000
Silver, silver content:					
Bullion	kilograms	481,000	84,400	279,000	46,100
Doré	do.	64,400	11,400	36,000	6,440
Metal powder, gross weight	do.	324,000	55,100	424,000	89,700
Nitrate, gross weight	do.	62,500	7,330	217,000	29,400
Ores and concentrates	do.	70,800	14,200	65,100	9,110
Semimanufactured forms containing 99.5% or more by weight of silver, gross weight	do.	122,000	28,700	148,000	35,200
Waste and scrap, gross weight	do.	1,310,000	223,000	1,670,000	377,000
Unwrought, other, gross weight	do.	75,100	14,400	57,500	11,500
Thorium and thorium-bearing materials, compounds	do.	2,520	318	4,640	478
Tin:					
Ingots and pigs	metric tons	6,770	38,100	6,640	35,300
Tin scrap and other tin bearing material, except tinplate scrap, includes rods, profiles, wire, powders, flakes, tubes, pipes	do.	33,200	56,100 r/	26,200	48,800
Tinplate and terneplate	do.	290,000	172,000	300,000	163,000
Titanium:					
Metal:					
Wrought, bars, rods, other	do.	5,260	239,000	5,380	253,000
Unwrought:					
Sponge and waste and scrap	do.	8,940	17,500	6,990	24,100
Other, billet, blooms, sheet bars, ingot	do.	2,470	58,400 r/	3,200	82,500
Ores and concentrates	do.	9,380	5,350	18,900	7,920
Pigments, dioxide and oxides	do.	384,000	627,000	464,000	784,000
Tungsten, tungsten content:					
Ammonium paratungstate	do.	103	911	53	489
Carbide powder	do.	701	16,900	969	19,000
Metal powders	do.	711	19,000	467	17,000
Miscellaneous tungsten-bearing materials, ferrotungsten, ferrosilicon tungsten, unwrought, waste and scrap, wrought, other metal, compounds	do.	1,340	33,900	1,310	35,400
Ores and concentrates	do.	26	826	70	2,050
Vanadium:					
Aluminum-vanadium master alloy, gross weight	kilograms	514,000	6,440	667,000	9,120
Ferrovanadium, vanadium content	do.	213,000	3,180	172,000	2,360
Metal, including waste and scrap, gross weight	do.	177,000	3,200	105,000	1,680
Pentoxide, anhydride, vanadium content	do.	747,000	4,270	653,000	3,360
Other oxides and hydroxides, vanadium content	do.	69,700	656	99,800	741

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Zinc:					
Compounds, chloride, compounds, n.s.p.f., oxide, sulfate	metric tons	16,100	20,100	22,600	55,200
Ores and concentrates, zinc content	do.	531,000	317,000	523,000	298,000
Slab	do.	1,880	2,220	2,770	3,380
Rolled	do.	3,870	5,500	3,530	5,350
Zirconium:					
Ore and concentrates	do.	69,500	27,300	72,900	34,000
Oxide, includes germanium oxides and zirconium oxides	do.	1,680	14,100	2,220	18,600 e/
Unwrought and waste and scrap	do.	156	3,160	180	3,620
Total		XX	24,600,000 r/	XX	28,200,000
Industrial minerals:					
Abrasives, manufactured:					
Aluminum oxide, crude	metric tons	9,020	20,400	9,020	23,500
Boron carbide	do.	17	652	29	481
Metallic abrasives	do.	26,600	17,900	28,900	18,600
Silicon carbide, crude, ground and refined	do.	8,560 r/	10,900 r/	10,000	11,500
Asbestos, includes reexports:					
Manufactured		NA	237,000	NA	288,000
Unmanufactured	metric tons	21,700	7,960	18,800	7,220
Barite, natural barium sulfate	do.	21,800	2,750	36,300	4,180
Boron minerals and compounds:					
Boric acid, includes orthoboric and anhydrous		107	56,700	119	64,400
Sodium borates		370	180,000	413	136,000
Bromine:					
Compounds, includes methyl bromine and ethylene dibromide, contained bromine	metric tons	8,020	16,000	7,740	26,200
Elemental	do.	2,110	2,430	1,870	2,560
Cement, hydraulic and clinker		694	55,200	738	64,200
Clays:					
Ball		107	6,080	100	8,660
Bentonite		719	75,300	761	80,300
Fire		189	16,500	216	18,600
Fuller's earth		152	24,600	136	25,000
Kaolin		3,310	567,000	3,690	621,000
Other, n.e.c., includes chamotte or dinas earth, activated clays and earths, artifically activated clays		329	133,000	357	142,000
Diamond, includes reexports, excludes industrial diamond	thousand carats	5,440	3,080,000	16,300	3,980,000
Diamond, industrial (exports and reexports):					
Powder, dust and grit, natural and synthetic	do.	101,000	68,100	100,000	71,800
Stones, unworked	do.	3,970	36,700	3,620	34,600
Diatomite		123	39,700	131	40,800
Feldspar	metric tons	9,880 r/	1,160	11,400	1,490
Fluorspar	do.	55,400	6,970	39,800	5,330
Garnet, industrial e/		10	5,000	10	5,000
Graphite, natural and artificial 2/	metric tons	102,000	82,800	94,100	96,500
Gypsum and gypsum products:					
Boards		52	22,900	58	27,100
Crude		112	11,000	161	12,600
Plasters		588	32,000	248	30,200
Other		XX	27,400	XX	32,200
Helium, grade-A	million cubic meters	27	47,400	37	66,000
Iodine, crude/resublimed and potassium iodide	metric tons	1,130	18,000	1,130	15,000
Iron oxide pigments and hydroxides:					
Pigment grade	do.	13,800	15,200	9,640	17,200
Other grade	do.	30,100	59,800	30,900	46,500
Lime		59	8,270 r/	73	9,960
Lithium chemicals:					
Carbonate	metric tons	2,710	9,670	2,770	9,630
Hydroxide	do.	4,940	21,200	4,780	31,100

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Industrial minerals--Continued:					
Magnesium compounds:					
Compounds, chlorides, hydroxide and peroxide, sulfates	metric tons	28,900	12,300	31,800	29,600
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	3,190	1,680	11,600	8,470
Crude	do.	28,900	3,520	29,500	3,460
Dead-burned and fused magnesia	do.	66,700	25,200	59,800	22,400
Other magnesia	do.	15,800	13,300	21,400	19,000
Mica:					
Scrap and flake:					
Powder	do.	7,320	4,010	8,880	4,610
Waste	do.	3,950	1,290	1,380	383
Sheet:					
Unworked	do.	452	2,150	209	343
Worked	do.	840	16,600	1,070	17,100
Peat		40	4,310	37	3,490
Perlite, processed and expanded e/	metric tons	47,000	1,570	43,000	1,450
Phosphate rock		272	11,400	299	12,100
Pumice and pumicite		23	10,100	27	15,300
Salt		892	37,000	642	37,800
Sand and gravel:					
Construction:					
Gravel		378	7,080	270	3,030
Sand		1,270	20,800	2,140	21,200
Industrial		1,670	133,000	1,660	179,000
Silica:					
Quartz crystal, cultured, electronic- and optical-grade	metric tons	90	25,400	74	22,800
Special silica stone products		NA	6,400	NA	6,400
Soda ash		3,620	447,000	3,900	477,000
Stone:					
Crushed		4,120	30,800	4,020	29,700
Dimension		XX	54,500	XX	59,800
Strontium:					
Carbonate, precipitated	metric tons	3,860	2,470	6,320	4,250
Oxide, hydroxide, peroxide	do.	854	470	862	466
Sulfur:					
Elemental		685	35,800	762	53,700
Sulfuric acid, 100% H_2SO_4	metric tons	155,000	16,800	191,000	15,800
Talc, excludes powders, talcum in (package), face, compact		147	27,200	154	32,800
Vermiculite e/		13 r/	1,640 r/	5	590
Wollastonite e/		20,000	8,000	7,000	2,800
Zeolites e/	metric tons	500 r/	100	200	40
Total		XX	5,990,000 r/	XX	7,160,000
Grand total		XX	30,600,000 r/	XX	35,300,000

e/ Estimated. r/ Revised. NA Not available. XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Artificial graphite includes large amounts of materials made from petroleum coke.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	4,000,000	6,200,000	3,910,000	6,860,000
Manufactures	do.	191,000	452,000	211,000	538,000
Antimony:					
Metal	do.	14,800	18,500	14,200	19,100

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Antimony--Continued:					
Ore and concentrate, antimony content	metric tons	2,870	3,350	3,690	4,250
Oxide, antimony content	do.	19,100	28,900	23,700	36,500
Arsenic:					
Acid	do.	4	24	--	--
Metal	do.	1,300	8,390	830	9,800
Trioxide	do.	29,100	14,700	31,100	15,500
Bauxite and alumina:					
Alumina, calcined equivalent		3,810	845,000	3,820	933,000
Bauxite:					
Calcined, refractory and other grade		299	28,000	310	26,600
Crude and dried		9,890	281,000	8,550	193,000
Speciality aluminum compounds, sulfate, chloride, fluoride-based	metric tons	51,200	31,500	46,700	26,000
Beryllium, ore, metal, and compounds	kilograms	136,000	2,620	164,000	3,260
Bismuth, metallic	do.	2,110,000	15,300	2,410,000	19,100
Cadmium:					
Metal	do.	294,000	848	425,000	1,510
Sulfide, gross weight	do.	18,400	95	45,400	169
Chromium:					
Chemicals	metric tons	22,900	39,600	29,100	27,300
Chromite ore	do.	252,000	15,700	268,000	17,100
Ferrochromium, metals, alloys	do.	649,000	334,000	608,000	339,000
Pigments and preparations based on chromium	do.	9,590	30,000	10,200	32,100
Cobalt:					
Metal:					
Alloys, articles, matte, wrought, waste and scrap	do.	819	22,600	1,120	29,300
Unwrought, excluding alloys and waste and scrap	do.	6,800	229,000	7,210	213,000
Oxide and hydroxides	do.	1,260	33,700	1,540	37,100
Other forms, includes acetates, carbonates, chlorides, sulfates	do.	1,610	12,400	1,710	11,000
Columbium (niobium) and tantalum:					
Columbium:					
Ferrocolumbium	do.	6,850	62,200	6,770	62,100
Ores and concentrates	do.	95	1,620	151	1,680
Oxide	do.	1,720 r/	30,600	1,700	29,200
Unwrought, alloys, metals, powder	do.	468	13,500	606	16,900
Tantalum:					
Ores and concentrates	do.	992	33,600	2,080	74,800
Unwrought, alloys, metal, powders, waste and scrap	do.	997	68,400	1,060	104,000
Wrought	do.	56	13,600	43	14,900
Copper:					
Scrap, alloyed and unalloyed	do.	108,000	168,000 r/	112,000	186,000
Semimanufactures	do.	313,000 r/	672,000 r/	397,000	1,000,000
Unmanufactured, does not include unalloyed scrap, copper content	do.	1,170,000	1,910,000	1,250,000	2,400,000
Ferroalloys not listed elsewhere:					
Ferrophosphorus	do.	10,600	3,050	13,000	3,310
Ferrotitanium and ferrosilicon-titanium	do.	4,750	8,620	6,050	15,900
Ferrozirconium	do.	100	173	281	548
Ferroalloys, other	do.	32,000	46,600	31,400	42,400
Gallium, unwrought and waste and scrap	kilograms	24,100	10,400	39,400	18,400
Germanium materials, gross weight	do.	12,400	10,400	8,210	9,240
Gold:					
Ash and residues	do.	133	1,760	60	1,800
Bullion, refined	do.	196,000	1,790,000	184,000	1,680,000
Compounds	do.	9,400	59,700	7,970	60,500
Doré and precipitates	do.	24,700	210,000	39,000	292,000
Metal powder	do.	5,500	48,700	6,720	58,800
Ores and concentrates	do.	117	1,130	65	636
Waste and scrap	do.	30,500	94,100	29,800	71,200
Indium, unwrought and waste and scrap	do.	77,400	14,500	69,400	9,620
Iron and steel:					
Cast iron and steel products		505	410,000	557	453,000 e/

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Iron and steel--Continued:					
Fabricated steel products		4,020	5,780,000	4,240	6,090,000 e/
Stainless steel	metric tons	696,000	1,680,000	757,000	1,830,000 e/
Steel mill products		32,400	12,600,000	34,400	13,400,000 e/
Iron and steel scrap:					
Direct-reduced iron, steelmaking grade		950	86,500	1,090	119,000
Ferrous, includes tinplate and ternplate, excludes used rails for rerolling and other uses, ships, boats, other vessels for scrapping		3,670	383,000	3,350	385,000
Pig iron, all grades		4,990	527,000	4,970	601,000
Ships, boats, other vessels for scrapping		(2/)	189	--	--
Used rails for rerolling and other uses, includes mixed (new plus used), rails		348	43,900	271	34,100
Iron ore		14,300	399,000	15,700	420,000
Lead, lead content:					
Base bullion	metric tons	90	58	65	30
Ore and concentrates	do.	12,300	3,100	31,200	7,810
Pigments and compounds, gross weight	do.	37,700	56,100	40,300	57,600
Pigs and bars	do.	311,000	175,000	356,000	190,000
Scrap, reclaimed, includes ash and residues	do.	--	--	25	5
Wrought, all forms, including wire and powders, gross weight	do.	11,800	18,300	9,200	19,300
Magnesium:					
Alloys, magnesium content	do.	56,500	180,000	56,300	164,000
Metal	do.	26,900	78,000	22,900	58,700
Powder, sheets, tubing, ribbons, wire, other forms, magnesium content	do.	594	2,260 r/	2,300	8,670
Waste and scrap	do.	6,780	7,690	9,890	16,400
Manganese, manganese content:					
Chemicals, manganese dioxide and potassium permanganate, gross weight	do.	42,600	61,200	52,700	75,700
Ferromanganese, all grades	do.	245,000	149,000	246,000	151,000
Metal, unwrought, waste and scrap, other, gross weight	do.	15,100	22,900	16,200	24,700
Ore and concentrates with 20% or manganese, all grades	do.	224,000	37,200 r/	227,000	32,100
Silicomanganese	do.	202,000	121,000	252,000	169,000
Mercury	do.	62	301	103	1,130
Molybdenum, molybdenum content:					
Ferromolybdenum	do.	5,160	37,300	5,310	35,600
Molybdates, all	do.	813	7,380	1,550	13,400
Ore and concentrates, roasted and other	do.	6,390	35,700	6,120	35,500
Oxides and hydroxides, gross weight	do.	746	5,100	1,210	7,400
Powders	do.	106	3,240	125	3,770
Unwrought	do.	13	542	16	328
Wire, gross weight	do.	8	638	17	894
Other, orange, mixtures of inorganic compounds, waste and scrap, other, gross weight	do.	2,030	14,500	2,100	14,600
Nickel, nickel content:					
Alloyed, gross weight	do.	13,300	184,000	19,000	270,000
Unwrought:					
Primary and chemicals, excludes carbonate	do.	139,000	854,000	156,000	1,410,000
Secondary	do.	9,480	54,800	10,700	91,900
Wrought	do.	1,090	17,900	992	20,400
Platinum-group metals, metal content:					
Iridium, unwrought and other forms	kilograms	2,250 r/	25,100	2,700	27,400
Osmium, unwrought	do.	23	272	133	1,130
Palladium, unwrought and other	do.	189,000	2,090,000	182,000	3,470,000
Platinum	do.	125,000 r/	1,150,000	94,000	1,360,000
Rhodium, unwrought and other forms	do.	10,300 r/	274,000 r/	18,200	851,000
Ruthenium, unwrought	do.	11,400	14,700	20,900	49,600
Rare-earths, estimated REO content:					
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates	do.	3,990,000	26,200	4,310,000	29,400
Compounds, including oxides, hydroxides, nitrates, other compounds except chlorides	do.	7,760,000	71,600	11,200,000	71,300
Ferrocerium and other pyrophoric alloys	do.	120,000	1,920	118,000	1,560
Metals, whether intermixed or alloyed	do.	1,780,000 r/	18,500	2,470,000	23,700

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Rare-earths, estimated REO content--Continued:					
Mixtures of rare-earth chlorides, except cerium chloride	kilograms	1,530,000	6,960	1,330,000	3,980
Mixtures of rare-earth oxides except cerium oxide	do.	5,980,000	15,500	2,190,000	9,530
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent	do.	161,000	3,200	58,400	2,590
Rhenium:					
Ammonium perrhenate	do.	2,750	1,670	7,450	3,830
Metal	do.	12,800	14,000	10,700	10,800
Selenium and tellurium:					
Selenium, selenium content:					
Unwrought and waste and scrap	do.	311,000	3,110	452,000	2,670
Selenium dioxide	do.	15,700	160	24,300	186
Tellurium, unwrought, and waste and scrap, gross weight	do.	38,000	1,440	52,300	1,800
Silicon, gross weight:					
Ferrosilicon	metric tons	246,000	160,000	322,000	193,000
Metal	do.	116,000	235,000	133,000	249,000
Silver, silver content:					
Ash and residues	kilograms	101,000	8,970	55,800	7,340
Bullion	do.	2,660,000	453,000	3,810,000	629,000
Doré	do.	407,000 r/	81,600	73,900	17,600
Metal powder, gross weight	do.	120,000	26,400	235,000	46,500
Nitrate, gross weight	do.	4,480 r/	364	24,200	1,770
Ore and concentrates:					
Base metal	do.	2,750	440	--	--
Silver	do.	10,800	1,970	1,420	229
Semimanufactured forms containing 99.5% or more by weight of silver, gross weight	do.	137,000 r/	23,900 r/	140,000	25,800
Waste and scrap, gross weight	do.	1,640,000	123,000 r/	1,130,000	134,000
Unwrought, other, gross weight	do.	126,000	22,200	204,000	37,200
Thallium, unwrought, waste and scrap, powders	do.	838	139	100	24
Thorium and thorium-bearing materials, compounds	do.	5,290	280	11,100	528
Tin, gross weight:					
Compounds	metric tons	411	3,550	586	4,740
Dross, skimmings, scrap, residues, alloys, n.s.p.f.	do.	3,870	7,840	5,170	17,700
Metal, unwrought	do.	47,500	255,000	44,900	244,000
Miscellaneous, includes tinfoil, tin powder, flitters, metallics, manufactures, n.s.p.f.	do.	NA	4,830	NA	5,680
Tinplate and terneplate	do.	449,000	255,000	359,000	206,000
Tinplate scrap	do.	58,000	5,270	14,500	1,660
Titanium:					
Concentrates:					
Ilmenite	do.	391,000	32,800	386,000	37,200
Rutile, natural and synthetic	do.	344,000	140,000	438,000	169,000
Slag	do.	678,000	265,000	533,000	219,000
Titaniferous iron ore	do.	10,700	2,620	88,200	4,890
Pigments, dioxides and oxides	do.	225,000	406,000	218,000	389,000
Metal:					
Unwrought:					
Ingots and billets	do.	1,380	20,400	1,540	23,200
Other, includes blooms, sheet, bars, slabs, other unwrought	do.	10	423	23	398
Powder	do.	224	1,170	250	2,610
Sponge	do.	6,000	42,200	7,240	49,900
Waste and scrap	do.	6,870	19,500	7,550	24,100
Wrought products, bars, castings, foil, pipes, plates, profiles, rods, sheet, strip, tubes, wire, other	do.	2,910	74,100	2,900	60,600
Tungsten, tungsten content:					
Ammonium paratungstate	do.	1,920	10,200	2,270	13,400
Ferrotungsten and ferrosilicon tungsten	do.	669	3,760	470	2,600
Miscellaneous tungsten-bearing materials, metal powders, carbide powder, unwrought, waste and scrap, wrought wire, plate, sheet, strip, foil, other, oxides, calcium tungstate, other tungstates, other compounds	do.	5,650	62,700	5,070	69,100

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Metals--Continued:					
Tungsten, tungsten content--Continued:					
Ores and concentrates	metric tons	2,870	12,400	2,370	11,100
Vanadium:					
Aluminum-vanadium master alloy, gross weight	kilograms	1,210,000	1,680	16,400	83
Ferrovanadium, vanadium content	do.	1,930,000	20,700	2,510,000	24,900
Metal, including waste and scrap, gross weight	do.	30,400	779	44,800	939
Miscellaneous chemicals, sulfates and vanadates, vanadium content	do.	174,000	1,650	149,000	1,070
Pentoxide, anhydride, vanadium content	do.	208,000	1,920	902,000	6,260
Vanadium-bearing ash, residues, slag from the manufacture of iron and steel, vanadium pentoxide content	do.	2,950,000	8,680	3,380,000	3,860
Other oxides and hydroxides, vanadium content	do.	--	--	13,500	231
Zinc:					
Compounds, lithopone, chloride, compounds n.s.p.f., hydrosulfite, oxide, sulfate	metric tons	78,700	75,800	87,400	83,800
Ore and concentrates, zinc content	do.	74,600	40,500	52,800	26,900
Rolled	do.	22,600	26,200	9,380	13,300
Slab, refined	do.	966,000	966,000	915,000	1,100,000
Zirconium and hafnium:					
Hafnium, unwrought, and waste and scrap	do.	9	1,770	11	2,240
Zirconium, ore and concentrates	do.	57,600	17,900	65,200	25,800
Zirconium oxide, includes germanium oxides and zirconium oxides	do.	3,140	27,800	3,950	35,000 e/
Zirconium, unwrought and waste and scrap	do.	859	46,700	1,040	52,700
Total		XX	45,700,000	XX	51,900,000
Industrial minerals:					
Abrasives, manufactured:					
Aluminum oxide, crude, ground and refined	metric tons	166,000	78,500	227,000	99,900
Boron carbide	do.	342	7,600	277	6,970
Metallic abrasives	do.	30,100	15,200 r/	33,500	17,600
Silicon carbide, crude, ground and refined	do.	169,000	79,500	190,000	94,300
Asbestos, chrysotile, crocidolite, other unspecified fibers	do.	15,800	3,150	14,600	2,510
Barite:					
Chemicals	do.	48,800	36,800	51,800	37,500
Crude	do.	836,000	43,500	2,070,000	92,400
Ground	do.	17,200	1,250	16,200	1,660
Other sulfates of	do.	17,500	14,300	15,400	14,000
Boron minerals and compounds:					
Borax		8	2,840	1	716
Boric acid		30	14,000	39	17,500
Colemanite		42	13,100	26	7,410
Ulexite		178	35,700	127	31,800
Bromine:					
Compounds, contained bromine	metric tons	7,140	31,200	14,500	31,100
Elemental	do.	1,970	2,110	5,470	3,730
Cement, hydraulic and clinker		29,400	1,140,000	28,700	1,070,000
Clays:					
Artifically activated clay and activated earth	metric tons	17,500	7,530	17,600	8,920
Bentonite	do.	8,930	2,990	8,470	2,930
Chamotte or dina's earth	do.	--	--	2	11
China clay or kaolin	do.	57,200	10,600	62,500	19,500
Common blue clay and other ball clay	do.	827	199	504	152
Decolorizing earths and fuller's earth	do.	398	19	70	12
Fire clay	do.	260	93	73	28
Other clay	do.	5,250	1,560	6,220	3,310
Diamond, industrial:					
Diamond stones, natural and miners'	thousand carats	3,130	14,300	2,520	13,400
Powder, dust and grit, natural and synthetic	do.	208,000	92,300	291,000	112,000
Diatomite	metric tons	387	332	529	316
Feldspar and nepheline syenite:					
Feldspar	do.	6,840	757	7,220	726
Nepheline syenite	do.	311,000	23,200	356,000	24,800

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999		2000	
		Quantity	Value	Quantity	Value
Industrial minerals--Continued:					
Fluorspar:					
Aluminum fluoride	metric tons	19,300	16,700	21,500	17,300
Cryolite	do.	9,560	7,160	9,190	6,730
Fluorspar	do.	478,000	56,900 r/	523,000	65,200
Hydrofluoric acid, HF	do.	120,000	120,000	131,000	131,000
Garnet, industrial e/		12	1,440	23	2,760
Gemstones, excludes pearls		XX	10,700,000	XX	12,900,000
Graphite:					
Natural	metric tons	55,800	34,700	60,800	32,500
Electric furnace electrodes	do.	62,800	135,000	60,900	128,000
Gypsum:					
Boards		1,710	294,000	783	113,000
Crude		9,340	88,900	9,210	89,300
Plasters		14	3,470	15	3,920
Other		XX	79,300	XX	62,600
Iodine, crude and potassium iodide	metric tons	5,430	88,100	5,270	77,000
Iron oxide pigments:					
Natural	do.	7,450	3,710	7,340	3,410
Synthetic	do.	77,600	69,300	84,000	73,300
Kyanite and related materials, andalusite	do.	6,290	1,320	6,440	1,320
Lime		140 r/	15,700 r/	113	13,500
Lithium chemicals:					
Carbonate	metric tons	13,800	20,800	14,800	23,800
Hydroxide	do.	254	1,630	615	2,100
Magnesium compounds:					
Compounds, chlorides, hydroxide, peroxide, sulfates	do.	58,500	24,000	104,000	29,800
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	123,000	19,100	136,000	22,100
Crude	do.	7,900	1,720	14,600	2,830
Dead-burned and fused magnesia	do.	392,000	75,000	501,000	88,200
Other magnesia	do.	17,900	14,900	18,900	14,100
Mica:					
Scrap and flake:					
Powder	do.	20,600	11,300	22,100	12,800
Waste	do.	5,070	1,150	6,180	1,290
Sheet:					
Unworked	do.	2,770	1,520	4,400	2,040
Worked	do.	1,780	12,800	1,310	12,000
Nitrogen, major compounds, gross weight		10,600	1,410,000	12,000	1,850,000
Peat moss	metric tons	752,000	149,000	786,000	157,000
Perlite, processed	do.	144,000	4,820	180,000	6,080
Phosphate rock and phosphatic materials		2,390	162,000	2,150	144,000
Potash, chloride, nitrate, sodium nitrate mixtures, sulfate	metric tons	7,360,000	566,000	7,580,000	555,000
Pumice:					
Crude or unmanufactured		353	11,600	384	11,900
Wholly or partially manufactured		1	2,000	1	1,810
Salt		8,870	137,000	8,960	127,000
Sand and gravel:					
Construction		1,920	24,400	2,870	33,300
Industrial		211	5,590	247	11,800
Silica:					
Quartz crystal, cultured, electronic- and optical-grade	metric tons	26	11,000	31	14,300
Special silica stone products		NA	6,200	NA	3,800
Soda ash		92	11,100	75	8,570
Stone:					
Crushed, chips, calcium carbonate fines		12,300	106,000	13,000	105,000
Dimension		NA	808,000	NA	925,000
Strontium:					
Carbonate	metric tons	44,000	25,700	49,300	27,600
Metal	do.	315	1,770	307	1,310
Nitrate	do.	590	2,290	687	2,350

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		1999 Quantity	1999 Value	2000 Quantity	2000 Value
Industrial minerals--Continued:					
Strontium--Continued:					
Oxide, hydroxide, peroxide	metric tons	267	600	192	466
Sulfate, celestite	do.	31,300	2,280	17,000	1,050
Sulfur:					
Elemental		2,580	51,600	2,330	39,400
Sulfuric acid, 100% H_2SO_4		1,370	62,600	1,420	41,500
Talc, unmanufactured		208	35,300	270	42,500
Vermiculite e/		71	13,300	59	11,100
Wollastonite e/		5,000	1,250	11,000	2,590
Zeolites e/	metric tons	200	40	100	20
Total		XX	17,200,000	XX	19,800,000
Grand total		XX	62,900,000 r/	XX	71,700,000

e/ Estimated. r/ Revised. NA Not available. XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

TABLE 9
COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES 1/

(Thousand metric tons unless otherwise specified)

Mineral or product		1999 World	1999 U.S.	1999 U.S. percent of world	2000 World	2000 U.S.	2000 U.S. percent of world
Metals:							
Mine: 2/							
Antimony	metric tons	108,000 r/	450 r/	0.4	118,000	W	NA
Arsenic trioxide 3/	do.	40,900 r/	--	--	36,900	--	--
Bauxite 3/ 4/		128,000 r/ 5/	NA	NA	135,000 5/	NA	NA
Beryl 3/	metric tons	6,220 r/	5,070	81.6 r/	5,650	4,510	79.8
Chromite 3/		14,100 r/	--	--	14,400	--	--
Cobalt	metric tons	30,600 r/	--	--	33,300	--	--
Columbium-tantalum concentrate 3/	do.	78,500 r/	--	--	79,300	--	--
Copper		12,700 r/	1,600	12.6 r/	13,200	1,440	10.9
Gold	kilograms	2,550,000 r/	341,000	13.4	2,550,000	353,000	13.9
Iron ore 3/		1,020,000 r/	57,700	5.7 r/	1,060,000	63,100	6.0
Lead		3,050 r/	520	17.0 r/	3,100	468	15.1
Manganese ore 3/		17,900 r/	--	--	20,200	--	--
Mercury	metric tons	1,630 r/ 5/	NA	NA	1,350 5/	NA	NA
Molybdenum	do.	128,000 r/	42,400 r/	33.1 r/	129,000	41,100	31.8
Nickel	do.	1,120,000	--	--	1,250,000	--	--
Platinum-group metals	kilograms	376,000 r/	12,700	3.4	365,000	13,400	3.7
Silver	metric tons	17,600 r/	1,950	11.1 r/	18,300	1,860	10.2
Tin	do.	216,000 r/	--	--	238,000	--	--
Titanium concentrates: 3/							
Ilmenite and leucoxene	do.	4,160,000 r/ 5/	W	NA	4,770,000	400,000 6/	8.4
Rutile	do.	359,000 r/ 5/	W	NA	417,000 5/	(7/)	NA
Tungsten	do.	36,100 r/	--	--	37,400	--	--
Zinc		8,040	813 r/	10.1 r/	8,730	829	9.5
Refinery: 8/							
Aluminum 9/		23,600 r/	3,780	16.0 r/	24,000	3,670	15.3
Bismuth	metric tons	3,360	--	--	4,070	--	--
Cadmium	do.	19,700 r/	1,190	6.0 r/	19,700	1,890	9.6
Cobalt 9/	do.	32,400 r/	--	--	35,200	--	--
Copper		14,600 r/	2,120 r/	14.5 r/	15,000	1,790	12.0
Iron and steel:							
Direct-reduced iron 9/		38,000 r/	1,670	4.4 r/	41,900	1,560	3.7
Iron, pig 9/		538,000 r/	46,300	8.6 r/	571,000	47,900	8.4
Steel, raw		789,000 r/	97,400	12.3 r/	846,000	102,000	12.1
Lead 10/		6,130 r/	1,460	23.9 r/	6,460	1,470	22.8

See footnotes at end of table.

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TABLE 9--Continued
COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES 1/

(Thousand metric tons unless otherwise specified)

Mineral or product		1999 World	1999 U.S.	1999 U.S. percent of world	2000 World	2000 U.S.	2000 U.S. percent of world
Metals--Continued:							
Magnesium	metric tons	438,000 r/	86,100 r/ 11/	19.7 r/	460,000	82,300 11/	17.9
Nickel 12/	do.	1,050,000	--	--	1,120,000	--	--
Selenium 9/	kilograms	1,400,000 r/ 5/	W	NA	1,460,000 5/	W	NA
Tellurium 9/	do.	116,000 r/ 5/	W	NA	138,000 5/	W	NA
Tin, smelter 13/	metric tons	262,000 r/	16,400 r/	6.3 r/	283,000	15,100	5.3
Zinc, smelter		8,570 r/	371	4.3 r/	9,050	371	4.1
Industrial minerals:							
Asbestos	metric tons	1,830,000 r/	7,190	0.4	1,900,000	5,260	0.3
Barite		6,360 r/	434 r/ 14/	6.8 r/	6,200	392 14/	6.3
Boron minerals		4,510 r/	1,220 14/	27.1 r/	4,380	1,070 14/	24.4
Bromine	metric tons	550,000 r/	239,000 14/	43.5 r/	542,000	228,000 14/	42.1
Celestite	do.	323,000 r/	--	--	318,000	--	--
Cement, hydraulic		1,600,000 r/	87,800 15/	5.5	1,640,000	89,500 15/	5.5
Clays:							
Bentonite		10,000 r/	4,070	40.6 r/	9,860	3,760	38.2
Fuller's earth		3,510 r/	2,560 r/	73.1 r/	3,870	2,910	75.3
Kaolin		41,100 r/	9,160	22.3 r/	41,200	8,800	21.3
Diamond, natural	thousand carats	117,000 r/	--	--	118,000	--	--
Diatomite	metric tons	1,960,000	747,000 14/	38.2 r/	1,890,000	677,000 14/	35.7
Feldspar		8,910 r/	875	9.8 r/	9,280	790	8.5
Fluorspar	metric tons	4,420,000 r/	-- 16/	--	4,520,000	-- 16/	--
Graphite, natural	do.	600,000 r/	--	--	602,000	--	--
Gypsum		106,000	22,400 r/	21.1 r/	106,000	19,500	18.5
Iodine, crude	metric tons	18,400 r/	1,620	8.8 r/	18,000	1,470	8.2
Lime		116,000 r/	19,700 r/ 14/	17.0 r/	116,000	19,600 14/ 15	16.8
Magnesite, crude		10,500 r/ 5/	W	NA	10,700 5/	W	NA
Mica, including scrap and flake 17/	metric tons	279,000 r/	95,400 r/	34.3 r/	290,000	101,000	34.9
Nitrogen, N content of ammonia		107,000 r/	12,900 r/ 18/	12.1 r/	109,000	12,300 18/	11.3
Peat		29,500 r/	731	2.5 r/	27,400	755	2.8
Perlite		1,960 r/	711 r/ 14/	36.4 r/	1,910	672 14/	35.1
Phosphate rock, gross weight		137,000 r/	40,600	29.7 r/	133,000	38,600	29.0
Potash, K_2O equivalent		25,600 r/	1,200	4.7	25,300	1,300	5.1
Pumice		12,000 r/	643 14/	5.4 r/	12,000	697 14/	5.8
Salt		211,000 r/	45,000 15/	21.3 r/	214,000	45,600 15/	21.4
Sand and gravel, industrial, silica		106,000 r/	28,900 14/	27.3 r/	106,000	28,500 14/	26.9
Soda ash, natural and manufactured 19/		33,200 r/	10,200	30.9 r/	34,200	10,200	30.0
Sulfur, all forms		57,700 r/	11,300	19.6 r/	57,200	10,300	18.0
Talc and pyrophyllite 20/		10,000 r/	925	9.2 r/	8,790	851	9.7
Vermiculite	metric tons	541,000 r/	175,000	32.3 r/	512,000	150,000	29.3

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "World" total. -- Zero.

1/ Data are rounded to no more than three significant digits.

2/ Content of ore and concentrate, unless otherwise specified.

3/ Gross weight.

4/ Individual country figures that are included in the world total represent dried bauxite equivalent of crude ore, but for some countries available data are insufficier to permit this adjustment.

5/ Does not include U.S. production.

6/ Includes rutile to avoid revealing company proprietary data. Rounded to one significant digit.

7/ Included with ilmenite to avoid revealing company proprietary data; not included in "World" total.

8/ Primary and secondary, unless otherwise specified.

9/ Primary.

10/ Includes bullion.

11/ Secondary production only. U.S. primary production is withheld to avoid disclosing company proprietary data.

12/ Refined nickel plus nickel content of ferronickel, nickel oxide, and other nickel salts.

13/ Includes tin content of alloys made directly from ore.

14/ Quantity sold or used by producers.

15/ Includes Puerto Rico.

16/ Shipments.

17/ Excludes, if any, U.S. production of low-quality sericite and sheet mica.

18/ Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

19/ U.S. production is natural only.

20/ Data for the United States exclude proprietary pyrophyllite production.

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MINING AND QUARRYING TRENDS

By Mary E. Ewell

Domestic survey data were prepared by the author and each of the statistical assistants who has responsibility for the commodities indicated.

The mining and quarrying trends shown in this report were calculated from nonfuel mineral data reported to the U.S. Geological Survey (USGS) by mining and quarrying companies operating in the United States. The data for 2000 were reported on the Mine, Development, and Mineral Exploration Supplement, a statistical survey conducted by the USGS, and on the production surveys for some more widely produced nonfuel mineral commodities, such as sand and gravel, for which the available data are extracted from computer files. Additional data for 2000 were derived from annual USGS production and consumption surveys of nonfuel mineral producers; these surveys covered 58 nonfuel mineral commodities produced in the United States.

Nonfuel minerals exclude coal, petroleum, coke, and related products.

As shown in this report, mining and quarrying data for 2000 include the annual data for construction sand and gravel and crushed and dimension stone. From 1981 to 1993, these mineral commodities were surveyed biennially and appeared alternately in this report. The inclusion of both sets of data in this report results in essentially a complete coverage of nonfuel mineral production in the United States. Comparisons of the 1994 to 2000 data with previously reported annual data, however, are not possible.

The data in the following tables are reported according to the primary product of a mine or operation. The primary product is usually determined by the product with the highest total value for the year. In some instances, the values of two products at the same operation are so close that the products are coproducts. To account for the data without double counting, however, a product of lesser value is considered to be a byproduct.

Total domestic mining of nonfuel mineral materials amounted to 5.4 billion metric tons (Gt) in 2000, about the same level as 1999. These materials included 4.0 Gt of crude ore mined or quarried and 1.4 Gt of mine waste and ore from development. Of the nonfuel mineral materials mined, 60% was for the production of industrial minerals and 40% was for the production of metals. Overall, 97% of nonfuel minerals was mined and quarried at surface level, and 3% was mined underground.

Total surface mining and quarrying for industrial minerals amounted to 3.2 Gt, remaining essentially the same as that of 1999. Crude ore mined at these surface operations was 2.8 Gt, and 355 million metric tons (Mt) was waste and ore from development. Underground mining for industrial minerals amounted to only 108 Mt, of which nearly all was crude ore.

Total surface mining for metal ores came to 2.1 Gt, slightly more than that of 1999. Of the 2.1 Gt, about 1.1 Gt was crude ore mined and the other 1.0 Gt was waste and ore from development. Underground mining of metal ores amounted to only 33 Mt, of which 97% was crude ore.

The major States in which mining for nonfuel minerals took place were, in order of total material handled, Nevada, Arizona, New Mexico, Minnesota, California, Florida, Texas, Michigan, Ohio, and Pennsylvania. These 10 States accounted for about 63% of the nonfuel minerals mined in the United States. Virtually all nonfuel mining in these States was conducted from the surface.

TABLE 1
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES, BY TYPE 1/

(Million metric tons)

	Surface 2/			Underground 3/			All mines		
Type of ore and year	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total
Metals:									
1996	1,160	1,600	2,760	49	3	51	1,210	1,600	2,810
1997	1,170	1,630	2,800	52	3	55	1,220	1,630	2,860
1998	1,100	1,500	2,600	50	3	53	1,150	1,500	2,650
1999	1,060 r/	1,050	2,110 r/	26	2	27	1,080 r/	1,050	2,130 r/
2000	1,110	1,020	2,130	32	1	33	1,140	1,030	2,160
Industrial minerals:									
1996	2,420 r/	434 r/	2,860 r/	112	3	114	2,530 r/	436 r/	2,970 r/
1997	2,520 r/	408 r/	2,920 r/	111	(5/)	111	2,630 r/	408 r/	3,030 r/
1998	2,750 r/	426 r/	3,180 r/	109	1	109	2,860 r/	427 r/	3,290 r/
1999	2,790	382 r/	3,170	106	(5/)	106	2,890	383 r/	3,280 r/
2000	2,800	355	3,150	108	(5/)	108	2,900	356	3,260

See footnotes at end of table.

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TABLE 1--Continued
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES, BY TYPE 1/

(Million metric tons)

Type of ore and year	Surface 2/			Underground 3/			All mines		
	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total
All mineral commodities:									
1996	3,580 r/	2,030	5,610 r/	160	6	166	3,740 r/	2,030 r/	5,780 r/
1997	3,690 r/	2,040	5,720 r/	163	4	167	3,850 r/	2,040	5,890 r/
1998	3,850 r/	1,930	5,780 r/	159	4	163	4,010 r/	1,930	5,940 r/
1999	3,840 r/	1,430	5,280 r/	132 r/	2	134 r/	3,980 r/	1,430	5,410 r/
2000	3,900	1,380	5,280	140	2	141	4,040	1,380	5,420

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes materials from wells, ponds, and pumping operations.

3/ Includes solution mining.

4/ Includes ore and waste from development operations.

5/ Less than 1/2 unit.

TABLE 2
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000, BY COMMODITY AND STATE 1/

(Thousand metric tons)

Type of ore or State	Number of mines 4/	Surface 2/			Underground 3/			All mines		
		Crude ore	Waste 5/	Total	Crude ore	Waste 5/	Total	Crude ore	Waste 5/	Total
Metal ore:										
Gold	48	198,000	645,000	843,000	3,880	409	4,280	202,000	646,000	848,000
Iron	11	189,000	143,000	331,000	W	--	W	189,000 6/	143,000	331,000
Zinc	10	W	W	W	5,700	W	5,700 7/	5,700 8/	W	15,300 7/
Other 9/	46	721,000	236,000	956,000	22,000	774	22,800	743,000	236,000	969,000
Total	115	1,110,000	1,020,000	2,130,000	31,600	1,180	32,800	1,140,000	1,020,000	2,160,000
Industrial mineral:										
Barite	6	860	W	860 7/	--	--	--	860	W	860
Clays	636	40,900	35,600	76,500	W	W	W	40,900 6/	35,600 6/	76,500
Diatomite	11	1,400	--	1,400	--	--	--	1,400	--	1,400
Feldspar 10/	12	1,080	W	1,080	--	--	--	1,080	W	1,080
Gypsum	54	15,700	3,660	19,300	2,500	--	2,500	18,200	3,660	21,800
Mica (scrap)	10	1,970	W	1,970 7/	--	--	--	1,970	W	1,970 7/
Phosphate rock	16	140,000	W	140,000 7/	--	--	--	140,000	W	140,000 7/
Pumice 11/	16	740	W	740 7/	--	--	--	740	W	740 7/
Salt	70	7,380	--	7,380	31,800	--	31,800 7/	39,100	--	39,100 7/
Sand and gravel:										
Construction	7,619	1,080,000	--	1,080,000	--	--	--	1,080,000	--	1,080,000
Industrial	155	27,700	--	27,700	W	--	W	27,700 6/	--	27,700
Soda ash	6	--	--	--	9,460	--	9,460	9,460	--	9,460
Stone:										
Crushed	3,453	1,470,000	117,000	1,590,000	50,000	342	50,300	1,520,000	118,000	1,640,000
Dimension	182	1,220	624	1,850	36	--	36	1,220	624	1,850
Talc and pyrophyllite	15	703	3,220	3,920	W	W	W	703 6/	3,220 6/	3,920
Tripoli	6	83	--	83	--	--	--	83	--	83
Other 12/	69	12,900	195,000	208,000	14,400	26	14,400	27,300	195,000	222,000
Total	12,336	2,800,000	355,000	3,150,000	108,000	368	108,000	2,900,000	356,000	3,260,000
Grand total	12,451	3,900,000	1,380,000	5,280,000	140,000	1,550	141,000	4,040,000	1,380,000	5,420,000
State:										
Alabama	182	64,100	6,120	70,200	W	W	W	64,100 6/	6,120 6/	70,200
Alaska	205	31,100	18,400	49,600	W	W	W	31,100 6/	18,400 6/	49,600
Arizona	249	W	W	W	W	--	W	W	W	W
Arkansas	174	40,400	5,390	45,800	W	--	W	40,400 6/	5,390	45,800
California	615	234,000	41,200	275,000	W	--	W	234,000 6/	41,200	275,000
Colorado	388	67,400	17,400	84,800	W	W	W	67,400 6/	17,400 6/	84,800
Connecticut	90	15,700	666	16,300	--	--	--	15,700	666	16,300
Delaware	14	2,330	--	2,330	--	--	--	2,330	--	2,330
Florida	189	242,000	W	242,000 7/	16	(13/)	16	242,000	W	242,000 7/
Georgia	243	94,300	16,000	110,000	1,380	9	1,390	95,600	16,000	112,000

See footnotes at end of table.

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TABLE 2--Continued
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000, BY COMMODITY AND STATE 1/

(Thousand metric tons)

Type of ore or State	Number of mines 4/	Surface 2/ Crude ore	Surface 2/ Waste 5/	Surface 2/ Total	Underground 3/ Crude ore	Underground 3/ Waste 5/	Underground 3/ Total	All mines Crude ore	All mines Waste 5/	All mines Total
State--Continued:										
Hawaii	29	6,380	461	6,840	--	--	--	6,380	461	6,840
Idaho	244	30,000	27,600	57,500	642	--	642	30,600	27,600	58,200
Illinois	296	105,000	6,140	111,000	3,270	23	3,300	109,000	6,170	115,000
Indiana	248	78,500	4,670	83,100	W	W	W	78,500 6/	4,670 6/	83,100
Iowa	398	46,500	3,250	49,800	6,470	W	6,470 7/	53,000	6,470 6/	56,200
Kansas	351	32,400	2,280	34,700	3,470	6	3,480	35,900	2,290	38,200
Kentucky	147	50,400	4,150	54,600	15,500	108	15,600	65,900	4,260	70,200
Louisiana	141	18,800	W	18,800 7/	14,500	--	14,500	33,300	W	33,300 7/
Maine	187	13,100	337	13,500	--	--	--	13,100	337	13,500
Maryland	90	44,200	2,800	46,900	W	W	W	44,200 6/	2,800 6/	46,900
Massachusetts	141	26,200	1,100	27,300	--	--	--	26,200	1,100	27,300
Michigan	610	166,000	W	166,000 7/	2,450	--	2,450	169,000	W	169,000 7/
Minnesota	555	197,000	96,600	293,000	--	--	--	197,000	96,600	293,000
Mississippi	112	14,400	1,070	15,500	--	--	--	14,400	1,070	15,500
Missouri	340	82,000	7,110	89,200	12,600	28	12,700	94,700	7,140	102,000
Montana	240	27,000	W	27,000 7/	1,010	W	1,010 7/	28,000	W	28,000 7/
Nebraska	165	16,300	476	16,800	W	W	W	16,300 6/	476 6/	16,800
Nevada	188	194,000	551,000	744,000	2,430	310	2,740	196,000	551,000	747,000
New Hampshire	96	12,600	326	12,900	--	--	--	12,600	326	12,900
New Jersey	101	38,500	1,710	40,200	--	--	--	38,500	1,710	40,200
New Mexico	180	W	W	W	W	W	W	W	W	W
New York	567	76,000	4,650	80,600	3,670	25	3,690	79,600	4,680	84,300
North Carolina	280	94,600	11,000	106,000	--	--	--	94,600	11,000	106,000
North Dakota	151	10,500	W	10,500 7/	--	--	--	10,500	W	10,500 7/
Ohio	373	123,000	7,310	131,000	W	W	W	123,000 6/	7,310 6/	131,000
Oklahoma	155	53,900	3,780	57,700	W	W	W	53,900 6/	3,780 6/	57,700
Oregon	344	37,000	2,750	39,700	--	--	--	37,000	2,750	39,700
Pennsylvania	366	109,000	7,990	117,000	5,520	31	5,550	114,000	8,020	122,000
Rhode Island	23	3,020	148	3,170	--	--	--	3,020	148	3,170
South Carolina	128	39,900	3,490	43,400	--	--	--	39,900	3,490	43,400
South Dakota	284	21,700	W	21,700 7/	W	--	W	21,700 6/	W	21,700 7/
Tennessee	203	64,700	5,340	70,100	9,800	W	9,800 7/	74,500	5,340 6/	79,900
Texas	532	198,000	11,500	209,000	W	W	W	198,000 6/	11,500 6/	209,000
Utah	274	109,000	W	109,000 7/	623	--	623	109,000	W	109,000 7/
Vermont	116	9,590	754	10,300	W	--	W	9,590 6/	754	10,300
Virginia	205	77,600	8,360	85,900	W	--	W	77,600 6/	8,360	85,900
Washington	412	60,700	1,640	62,300	W	W	W	60,700 6/	1,640 6/	62,300
West Virginia	60	13,000	1,060	14,000	2,910	W	2,910 7/	15,900	1,060 6/	16,900
Wisconsin	610	73,800	2,730	76,500	--	--	--	73,800	2,730	76,500
Wyoming	160	16,800	3,190	20,000	14,500	--	14,500	31,300	3,190	34,500
Undistributed 14/	--	722,000	487,000	1,210,000	38,800	1,010	39,800	761,000	485,000	1,250,000
Total	12,451	3,900,000	1,380,000	5,280,000	140,000	1,550	141,000	4,040,000	1,380,000	5,420,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed." -- Zero.

1/ Data are rounded to no more than three significant digits, except number of mines; may not add to totals shown.

2/ Includes materials from wells, ponds, and pumping operations.

3/ Includes solution mining.

4/ Includes quarries and other mineral operations.

5/ Includes ore and waste from development operations.

6/ Excludes materials from underground operations.

7/ Excludes waste from mining operations and ore and waste from development operations.

8/ Excludes materials from surface operations.

9/ Includes beryllium, copper, gold-silver, lead, magnesium metal, molybdenum, platinum and palladium, rare-earth metal concentrates, silver, titanium, uranium, and metals indicated by symbol W.

10/ Includes aplite.

11/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

12/ Includes abrasives, boron minerals, bromine, diatomite, emery, greensand marl, iodine, iron oxide pigments, kyanite, lithium minerals, magnesite, olivine, perlite, potash, sericite, sulfur (Frasch), vermiculite, wollastonite, zeolites, and industrial minerals indicated by symbol W.

13/ Less than 1/2 unit.

14/ Includes States indicated by symbol W.

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TABLE 3
VALUE OF PRINCIPAL MINERAL PRODUCTS AND BYPRODUCTS OF SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000 1/

(Dollars per metric ton)

Type of ore and commodity	Surface			Underground			All mines		
	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total
Metal:	6.61	0.50	7.11	48.74	5.84	54.58	7.17	0.60	7.77
Gold	9.91	0.24	10.15	70.30	0.44	70.74	10.37	0.10	10.47
Iron	7.60	--	7.60	W	--	W	7.60 2/	--	7.60
Zinc	W	W	W	53.25	W	53.25 4/	53.25 3/	W	53.25 4/
Industrial mineral:	6.42	0.02	6.45	15.29	--	15.29	6.76	0.02	6.98
Clays	37.44	--	37.44	W	--	W	37.44 2/	--	37.44
Diatomite	130.37	--	130.37	--	--	--	130.37	--	130.37
Feldspar 5/	31.63	W	31.63 4/	--	--	--	31.63	W	31.63 4/
Garnet	127.28	--	127.28	--	--	--	127.28	--	127.28
Gypsum	8.46	--	8.46	8.01	--	8.01	8.40	--	8.40
Iodine	16,257.49	--	16,257.49	--	--	--	16,257.49	--	16,257.49
Magnesium compounds	77.65	W	77.65 4/	--	--	--	77.65	W	77.65 4/
Mica (scrap)	15.94	W	15.94 4/	--	--	--	15.94	W	15.94 4/
Pumice 6/	24.22	--	24.22	--	--	--	24.22	--	24.22
Salt	63.91	--	63.91	14.65	--	14.65 4/	22.55	W	22.55 4/
Sand and gravel:									
Construction	4.81	W	4.81 4/	--	--	--	4.81	W	4.81 4/
Industrial	19.58	W	19.58 4/	W	--	W	19.58 2/	W	19.58 4/
Soda ash	--	--	--	65.89	--	65.89	65.89	--	65.89
Stone:									
Crushed	5.38	W	5.38 4/	5.38	--	5.38	5.38	W	5.38 4/
Dimension	185.38	--	185.38	W	--	W	185.38	--	185.38
Talc and pyrophyllite	27.12	--	27.12 4/	W	--	W	27.12 2/	W	27.12 4/
Average, industrial minerals, excluding sand and gravel and stone 7/	19.16	0.29	19.45	23.03	--	23.03	20.01	0.23	20.24
Average, metals and industrial minerals 7/ 8/	6.34	0.10	6.44	24.21	1.51	25.72	6.60	0.11	6.71
Average, metals and industrial minerals, excluding sand and gravel and stone 7/ 8/	8.85	0.22	9.07	33.78	2.31	36.08	9.80	0.30	10.10

W Withheld to avoid disclosing company proprietary data; included with appropriate "Average." -- Zero.
1/ Values calculated from unrounded data; may not add to totals shown because of independent rounding.
2/ Value of products at surface operations only.
3/ Value of products at underground operations only.
4/ Value of principal mineral product only.
5/ Includes aplite.
6/ Excludes volcanic cinder and scoria; included with crushed and broken stone.
7/ Includes values of beryllium concentrate, copper, gold-silver ore, lead, magnesium metal, molybdenum, platinum and palladium, rare-earth metal concentrate, silver, titanium, and metals indicated by symbol W.
8/ Includes values of abrasives, asbestos, barite, boron minerals, bromine, clays, emery, greensand marl, iron oxide pigments, kyanite, lithium minerals, magnesite, olivine, perlite, phosphate rock, potash, sericite, soda ash, sulfur (Frasch), tripoli, vermiculite, wollastonite, zeolites, and industrial minerals indicated by symbol W.

TABLE 4
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT OF CRUDE ORE

Type of ore and name of mine, quarry, or operation 1/	State	Operator	Commodity	Mining method
Metal ore:				
Morenci	Arizona	Phelps Dodge Corp.	Copper-molybdenum ore	Open pit.
Tyrone	New Mexico	do.	Copper ore	Do.
Sierrita	Arizona	do.	Copper-molybdenum ore	Do.
Bagdad	do.	do.	Copper ore	Do.
Bingham Canyon	Utah	Kennecott Utah Copper Corp.	do.	Do.
Chino	New Mexico	Phelps Dodge Corp.	Copper-molybdenum ore	Do.
Minntac	Minnesota	USX Corp.	Iron ore	Do.
Miami (Inspiration)	Arizona	Phelps Dodge Corp.	Copper ore	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	Gold ore	Do.
Carlin Mines Complex (7)	do.	Newmont Gold Co.	do.	Open pit and stoping.
Hibbing Taconite Co.	Minnesota	Cleveland-Cliffs, Inc.	Iron ore	Open pit.

See footnotes at end of table.

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TABLE 4--Continued
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT OF CRUDE ORE

Type of ore and name of mine, quarry, or operation 1/	State	Operator	Commodity	Mining method
Metal ore--Continued:				
Empire Iron Mining Partnership	Michigan	Cleveland-Cliffs, Inc.	Iron ore	Open pit.
LTV Steel Mining Co.	Minnesota	do.	do.	Do.
Mission Complex	Arizona	ASARCO Inc.	Copper ore	Open pit and stoping.
Ray	do.	do.	do.	Open pit.
National Steel Pellet Co.	Minnesota	National Steel Pellet Co.	Iron ore	Do.
Tilden Mining Co.	Michigan	Cleveland-Cliffs, Inc.	do.	Do.
Fort Knox	Alaska	Fairbanks Gold Mining Inc.	Gold ore	Do.
Cortez	Nevada	Placer Dome Inc.	do.	Do.
Mesquite	California	Newmont Gold Co.	do.	Do.
Northshore Mining Co.	Minnesota	Cleveland-Cliffs, Inc.	Iron ore	Do.
Thunderbird	do.	EVTAC Mining Co.	do.	Do.
Betze-Post/Goldstrike	Nevada	Barrick Gold Corp.	Gold ore	Do.
Rochester	do.	Coeur d'Alene Mines Corp.	Gold ore-silver	Do.
Cresson	Colorado	Cripple Creek & Victor Gold Mining Co.	Gold ore	Do.
Industrial mineral:				
Florida mines (6)	Florida	IMC-Agrico Co.	Phosphate rock	Do.
Florida mines (2)	do.	Cargill Fertilizer Inc.	do.	Do.
South Pasture	do.	C F Industries, Inc.	do.	Do.
Florida mines	do.	PCS Phosphate Co., Inc.	do.	Do.
F.E.C. Quarry	do.	CSR America, Inc.	Stone	Open quarry.
Aurora	North Carolina	PCS Phosphate Co., Inc.	Phosphate rock	Open pit.
Georgetown	Texas	Texas Crushed Stone Co., Inc.	Stone	Open quarry.
Beckmann	do.	Martin Marietta Aggregates, Inc.	do.	Do.
White Rock Quarries	Florida	Vecellio & Grogan, Inc.	do.	Dredging.
McCook 378	Illinois	Vulcan Materials Co.	do.	Open quarry.
Pennsuco	Florida	Tarmac America, Inc.	do.	Do.
IMC-Carlsbad	New Mexico	IMC Kalium Ltd.	Potash	Stoping.
Thornton	Illinois	General Dynamics Corp.	Stone	Open quarry.
Calcite Operation	Michigan	Michigan Limestone Operations	do.	Do.
Stoneport Quarry	do.	Lafarge Corp.	do.	Do.
Bridgeport Stone Plant	Texas	TXI Operations, L.P.	do.	Do.
IMC-Ogden	Utah	IMC Kalium Ltd.	Potash	Stoping.
Crushed Limestone Operation	Missouri	Tower Rock Stone Co.	Stone	Open quarry.
Hunter Quarry	Texas	Hunter Industries, Inc., Colorado Materials Co.	do.	Do.
Three Rivers	Kentucky	Martin Marietta Aggregates, Inc.	do.	Do.
Reed Quarry	do.	Vulcan Materials Co.	do.	Do.
GKK Mines	Florida	GKK Corp.	do.	Do.
Norcross	Georgia	Vulcan Materials Co.	do.	Do.
Servtex	Texas	Hanson Building Materials America	do.	Do.
Delaware	Ohio	The National Lime & Stone Co.	do.	Do.

1/ Owing to commodity reporting differences, the rank of individual mining operations may not be available.

TABLE 5
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT OF TOTAL MATERIAL HANDLED

Type of ore and name of mine, quarry, or operation 1/	State	Operator	Commodity	Mining method
Metal ore:				
Morenci	Arizona	Phelps Dodge Corp.	Copper-molybdenum ore	Open pit.
Bingham Canyon	Utah	Kennecott Utah Copper Corp.	do.	Do.
Barrick Goldstrike	Nevada	Barrick Gold Corp.	Gold ore	Open pit and stoping.
Tyrone	New Mexico	Phelps Dodge Corp.	Copper ore	Open pit.
Twin Creeks	Nevada	Newmont Gold Co.	Gold ore	Do.
Mission Complex	Arizona	ASARCO Inc.	Copper ore	Do.
Carlin Mines Complex (7)	Nevada	Newmont Gold Co.	Gold ore	Open pit and stoping.
Round Mountain	do.	Round Mountain Gold Corp.	do.	Open pit.
Sierrita	Arizona	Phelps Dodge Corp.	Copper ore	Open pit.
Cortez	Nevada	Placer Dome Inc.	Gold ore	Do.
Ray	Arizona	ASARCO Inc.	Copper ore	Do.

See footnotes at end of table.

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TABLE 5--Continued
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT OF TOTAL MATERIAL HANDLED

Type of ore and name of mine, quarry, or operation 1/	State	Operator	Commodity	Mining method
Metal ore--Continued:				
Bagdad	Arizona	Phelps Dodge Corp.	Copper ore	Open pit.
Minntac	Minnesota	USX Corp.	Iron ore	Do.
Empire Iron Mining Partnership	Michigan	Cleveland-Cliffs, Inc.	do.	Do.
Chino	New Mexico	Phelps Dodge Corp.	Copper-molybdenum ore	Do.
LTV Steel Mining Co.	Minnesota	Cleveland-Cliffs, Inc.	Iron ore	Do.
Lone Tree	Nevada	Newmont Gold Co.	Gold ore	Do.
Hibbing Taconite Co.	Minnesota	Cleveland-Cliffs, Inc.	Iron ore	Do.
Robinson	Nevada	BHP Copper Co.	Gold and copper ore	Do.
Miami (Inspiration)	Arizona	Phelps Dodge Corp.	Copper ore	Do.
Jerritt Canyon	Nevada	Independence Mining Co., Inc.	Gold ore	Do.
Fort Knox	Alaska	Fairbanks Gold Mining Inc.	do.	Do.
Tilden Mining Co.	Michigan	Cleveland-Cliffs, Inc.	Iron ore	Do.
Thompson	Idaho	Thompson Creek Metals Co.	Molybdenum ore	Do.
Golden Sunlight	Montana	Placer Dome Inc.	Gold ore	Do.
Industrial mineral:				
Florida mines (6)	Florida	IMC-Agrico Co.	Phosphate rock	Do.
Florida mines (2)	do.	Cargill Fertilizer Inc.	do.	Do.
South Pasture	do.	C F Industries, Inc.	do.	Do.
Aurora	North Carolina	PCS Phosphate Co., Inc.	do.	Do.
F.E.C. Quarry	Florida	CSR America, Inc.	Stone	Open quarry.
Florida mines	do.	PCS Phosphate Co., Inc.	Phosphate rock	Open pit.
Georgetown	Texas	Texas Crushed Stone Co., Inc.	Stone	Open quarry.
Beckmann	do.	Martin Marietta Aggregates, Inc.	do.	Do.
White Rock Quarries	Florida	Vecellio & Grogan, Inc.	do.	Dredging.
McCook 378	Illinois	Vulcan Materials Co.	do.	Open quarry.
Pennsuco	Florida	Tarmac America, Inc.	do.	Do.
Thornton	Illinois	General Dynamics Corp.	do.	Do.
Calcite Operation	Michigan	Michigan Limestone Operations	do.	Do.
Stoneport Quarry	do.	Lafarge Corp.	do.	Do.
IMC-Carlsbad	New Mexico	IMC Kalium Ltd.	Potash	Stoping.
Bridgeport Stone Plant	Texas	TXI Operations, L.P.	Stone	Open quarry.
Crushed Limestone Operation	Missouri	Tower Rock Stone Co.	do.	Do.
IMC-Ogden	Utah	IMC Kalium Ltd.	Potash	Stoping.
Hunter Quarry	Texas	Hunter Industries, Inc., Colorado Materials Co.	Stone	Open quarry.
Three Rivers	Kentucky	Martin Marietta Aggregates	do.	Do.
Reed Quarry	do.	Vulcan Materials Co.	do.	Do.
Teichert Aggregates	California	A. Teichert & Son, Inc.	Sand and gravel	Open pit.
GKK Mines	Florida	GKK Corp	Stone	Open quarry.
Norcross	Georgia	Vulcan Materials Co.	do.	Do.
Thornton	Illinois	General Dynamics Corp.	do.	Do.

1/ Owing to commodity reporting differences, the rank of individual mining operations may not be available.

TABLE 6
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000, BY SELECTED COMMODITY AND STATE 1/

(Thousand metric tons)

Type of ore or State	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
Metal ore:						
Copper	1,440 2/	W	1,440	W	W	W
Gold	W	W	W	253,000	4,220	257,000
Iron ore (usable)	57,500 2/	W	57,500	189,000 3/	W	189,000
Zinc	691 2/	W	691	12,300 3/	W	12,300
Industrial mineral:						
Barite	W	--	W	860	--	860
Clays	40,800 2/	W	40,800	40,800 3/	W	40,800
Diatomite	676	--	676	1,330	--	1,330

See footnotes at end of table.

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TABLE 6--Continued
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000, BY SELECTED COMMODITY AND STATE 1/

(Thousand metric tons)

Type of ore or State	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
Industrial mineral--Continued:						
Feldspar 4/	990	--	990	1,250	--	1,250
Gypsum	15,400	2,500	17,900	15,700	2,500	18,200
Iodine	1	--	1	1	--	1
Magnesium compounds	314	--	314	--	--	--
Mica (scrap)	154 2/	W	154	1,780	--	1,780
Perlite	672	--	672	730	--	730
Phosphate rock	35,000	--	35,000	140,000	--	140,000
Pumice 5/	697	--	697	698	--	698
Salt	W	37,800 6/	37,800	W	44,100 7/	44,100
Sand and gravel:						
Construction	1,120,000	--	1,120,000	1,120,000	--	1,120,000
Industrial	28,600 2/	W	28,600	28,600 3/	W	28,600
Soda ash	--	8,540	8,540	--	10,200	10,200
Stone:						
Crushed	1,510,000	49,100	1,560,000	1,510,000	50,000	1,560,000
Dimension	1,260 2/	W	1,260	1,260 3/	W	1,260
Talc and pyrophyllite	933 2/	W	933	930 3/	W	930
Tripoli	72	--	72	83	--	83
State:						
Alabama	68,100 2/	W	68,100	68,100 3/	W	68,100
Alaska	--	--	--	29,200 3/	W	29,200
Arizona	46,000 2/	W	46,000	340,000 3/	W	340,000
Arkansas	41,100 2/	W	41,100	41,100 3/	W	41,100
California	215,000 2/	W	215,000	229,000 3/	W	229,000
Colorado	57,800 2/	W	57,800	66,800	5	66,800
Connecticut	15,800	--	15,800	15,800	--	15,800
Delaware	2,330	--	2,330	2,330	--	2,330
Florida	145,000	16	145,000	245,000	16	245,000
Georgia	94,300	1,380	95,700	96,000	1,380	97,400
Hawaii	6,380	--	6,380	6,380	--	6,380
Idaho	33,200 2/	W	33,200	87,000 3/	W	87,000
Illinois	108,000	3,270	111,000	108,000	3,270	111,000
Indiana	84,700 2/	W	84,700	84,700 3/	W	84,700
Iowa	48,500	6,470	55,000	48,500	6,470	55,000
Kansas	34,500	3,460	37,900	34,500	3,460	37,900
Kentucky	52,200	15,500	67,700	52,200	15,500	67,700
Louisiana	20,200	12,500	32,700	21,000	13,200	34,200
Maine	13,400	--	13,400	13,400	--	13,400
Maryland	45,500 2/	W	45,500	45,500 3/	W	45,500
Massachusetts	26,700	--	26,700	26,700	--	26,700
Michigan	135,000	2,170	138,000	167,000	2,440	170,000
Minnesota	94,300	--	94,300	199,000	--	199,000
Mississippi	15,800	--	15,800	15,800	--	15,800
Missouri	84,500	4,080	88,600	84,500	5,310	89,800
Montana	13,600 2/	W	13,600	24,300	1,000	25,300
Nebraska	18,500 2/	W	18,500	22,700 3/	W	22,700
Nevada	47,800	--	47,800	126,000 3/	W	126,000
New Hampshire	12,600	--	12,600	12,600	--	12,600
New Jersey	43,000	--	43,000	43,000	--	43,000
New Mexico	17,600 2/	W	17,600	W	W	W
New York	80,600 2/	W	80,600	80,700	5,500	86,200
North Carolina	90,300	--	90,300	96,600	--	96,600
North Dakota	10,700	--	10,700	10,700	--	10,700
Ohio	132,000 2/	W	132,000	132,000 3/	W	132,000
Oklahoma	54,900 2/	W	54,900	54,900 3/	W	54,900
Oregon	38,000	--	38,000	38,200	--	38,200
Pennsylvania	118,000 2/	W	118,000	114,000	5,520	119,000
Rhode Island	3,200	--	3,200	3,200	--	3,200
South Carolina	42,000	--	42,000	42,300	--	42,300
South Dakota	18,500	--	18,500	23,000 3/	W	23,000

See footnotes at end of table.

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TABLE 6--Continued
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2000, BY SELECTED COMMODITY AND STATE 1/

(Thousand metric tons)

Type of ore or State	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
State--Continued:						
Tennessee	67,800 2/	W	67,800	67,800	9,830	77,600
Texas	208,000	11,000	219,000	208,000	11,200	219,000
Utah	43,800	369	44,200	50,400	596	51,000
Vermont	10,100 2/	W	10,100	10,100 3/	W	10,100
Virginia	83,000 2/	W	83,000	85,800 3/	W	85,800
Washington	61,700	--	61,700	62,200 3/	W	62,200
West Virginia	14,800	2,910	17,700	14,800	2,910	17,700
Wisconsin	75,100	--	75,100	75,100	--	75,100
Wyoming	16,000	7,240	23,200	17,000	14,500	31,500

W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes marketable product from underground operations.
3/ Includes ore treated at underground operations.
4/ Includes aplite.
5/ Excludes volcanic cinder and scoria; included with crushed and broken stone.
6/ Includes ore treated at surface operations.
7/ Includes marketable product from surface operations.

TABLE 7
MINING METHODS USED AT SURFACE OPERATIONS IN THE UNITED STATES, BY COMMODITY, IN 2000

(Percentage of total material handled)

Type of ore and commodity	Preceded by drilling and blasting	Not preceded by drilling and blasting 1/
Metal ore:	97	3
Beryllium	100	--
Copper	100	--
Gold	99	1
Gold-silver	100	--
Iron	94	6
Magnesium metal	96	4
Molybdenum	100	--
Rare-earth metals	100	--
Silver	100	--
Titanium	--	100
Uranium	--	100
Zinc	100	--
Industrial mineral:	50	50
Abrasives	100	--
Barite	2	98
Boron minerals	100	--
Bromine	--	100
Clays	--	100
Diatomite	4	96
Emery	100	--
Feldspar 2/	63	37
Garnet	41	59
Greensand marl	--	100
Gypsum	98	2
Iodine	--	100
Iron oxide pigments	77	23
Kyanite	100	--
Lithium minerals	--	100
Magnesite	100	--
Magnesium compounds	30	70

See footnotes at end of table.

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TABLE 7--Continued
MINING METHODS USED AT SURFACE OPERATIONS
IN THE UNITED STATES, BY COMMODITY, IN 2000

(Percentage of total material handled)

Type of ore and commodity	Preceded by drilling and blasting	Not preceded by drilling and blasting 1/
Industrial mineral--Continued:		
Mica (scrap)	1	99
Olivine	57	43
Perlite	16	84
Phosphate rock	2	98
Potash	--	100
Pumice 3/	6	94
Salt	1	99
Sand and gravel:		
Construction	--	100
Industrial	--	100
Sericite	100	--
Stone:		
Crushed	99	1
Dimension	--	100
Sulfur (Frasch)	--	100
Talc and pyrophyllite	86	14
Tripoli	95	5
Vermiculite	91	9
Wollastonite	100	--
Zeolites	100	--
Metal ores and industrial minerals	69	31

-- Zero.
1/ Includes drilling and cutting without blasting, dredging, mechanical excavation and nonfloat washing, and other surface mining methods.
2/ Includes aplite.
3/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

TABLE 8
EXPLORATION ACTIVITY IN THE UNITED STATES IN 2000, BY METHOD, COMMODITY, AND STATE 1/

(Meters)

Commodity or State	Method of exploration: Churn drilling	Diamond drilling	Percussion drilling	Rotary and reverse circulation drilling	Other drilling	Trenching	Total
Commodity:							
Gold	--	96,900	--	339,000	W	4,210	440,000
Zinc	--	18,600	W	--	W	--	18,600
Other 2/	(3/)	12,400	(3/)	39,800	68,900	26	121,000
Total	(3/)	128,000	(3/)	378,000	68,900	4,240	579,000
Percent of total	(3/)	22	(3/)	65	12	1	100
State:							
Alaska	--	22,600	--	36,500	--	979	60,000
Colorado	--	3,030	--	71,800	--	--	74,800
Nevada	--	72,900	--	229,000	W	1,610	304,000
Tennessee	--	10,600	W	--	W	--	10,600
Utah	--	366	--	W	--	--	366
Undistributed 4/	(3/)	18,500	(3/)	41,000	68,900	1,650	130,000
Total	(3/)	128,000	(3/)	378,000	68,900	4,240	579,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes beryllium concentrate, boron minerals, copper, diatomite, iron, manganese, silver, uranium, and commodities indicated by symbol W.
3/ Withheld to avoid disclosing company proprietary data; included with "Other drilling."
4/ Includes California, Idaho, Minnesota, New Mexico, Oregon, South Dakota, Wyoming, and States indicated by symbol W.

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ABRASIVES, MANUFACTURED

By Donald W. Olson

Domestic survey data and tables were prepared by Christine K. Pisut, statistical assistant.

Abrasives play an important role in the fashioning and finishing of numerous products with a wide range of end-use applications. Abrasives are natural or manufactured substances that are used to abrade, clean, etch, grind, polish, scour, or otherwise remove solid material by rubbing action (as in a grinding wheel) or impact (as in pressure blasting). The most important physical properties for abrasives are hardness ("scratch" hardness), toughness (rigidity), friability, grain shape and size, character of fracture (cleavage), and purity (uniformity). Additional considerations include thermal stability, bonding characteristics, cost, and availability. Manufactured abrasives are made from metals or minerals by heating or chemically treating them to enhance or give them abrasive physical properties. No single property is paramount for any use (Wellborn, 1996, p. 31, 43).

Manufactured abrasives generally dominate high-grade abrasive markets as opposed to natural abrasives because they have superior physical properties and more uniform quality and can be tailored to meet user needs. Consequently, manufactured abrasives typically are characterized by premium prices relative to natural abrasive minerals. Even though manufactured abrasives are more expensive, their durability and efficiency have proven to be more cost-effective. Therefore, they are preferred in many industrial applications, such as metal finishing, cutting, and polishing.

This report includes information on the following abrasives: aluminum-zirconum oxide, boron carbide, fused aluminum oxide, metallic shot and grit, and silicon carbide. In some cases, United States production data were combined with Canadian output to protect proprietary information. Trade data in this report are from the U.S. Census Bureau. Quantities are reported in metric units unless otherwise noted.

Combined Canadian and United States production of aluminum oxide increased, while production of silicon carbide declined in 2000 from that of 1999. U.S. imports of crude, ground, and refined silicon carbide and of ground and refined aluminum oxide increased. U.S. metallic abrasives production decreased compared with that of 1999.

Fused Aluminum Oxide

Legislation and Government Programs.—As of January 1, 2000, the national defense stockpile (NDS) maintained by the U.S. Department of Defense (DOD) contained about 37,700 metric tons (t) of crude fused aluminum oxide valued at $7.3 million and about 17,700 t of fused aluminum oxide abrasive grain valued at $6.7 million. During 2000, the DOD reported sales of all NDS crude fused aluminum oxide for $8.7 million and sales of about 1,300 t of NDS aluminum oxide abrasive grain for $627,960. Under Federal legislation authorizing the disposal of all NDS aluminum oxide, the DOD plans to continue such sales until all the stockpiled aluminum oxide is sold (Janet Rollins, Market Analyst, Defense National Stockpile Center, oral commun., 2001). All the stockpiled aluminum

Manufactured Abrasives in the 20th Century

Silicon carbide was the first synthetic abrasive to be produced and the first to be commercialized. In 1891, the electric-furnace method for making silicon carbide was developed, beginning a revolution in the high-grade abrasives industry. Before that time, all abrasives were natural minerals and rocks, except for some minor use of chemically prepared materials. Silicon carbide was initially marketed under the trade name Carborundum. By 1900, U.S. production of Carborundum had already increased to about 1,200 metric tons with an estimated value of $263,000. Carborundum was mainly used by lapidaries in place of diamond powder, and as an abrasive material, it was made into hones and wheels. The only other manufactured abrasive in 1900 was crushed steel, for which domestic production was about 320 tons valued at $50,000. The largest part of the crushed steel production was used in the stonecutting trade, particularly for marble and granite. Very fine grades of crushed steel, also known as steel emery and rouge, were used by lens and other glass grinders.

By 2000, manufactured abrasives, with the exceptions of diamond and garnet, dominated the field of high-grade abrasives. Manufactured abrasives became essential to modern industry because they were more uniform in their properties and in their quality than most natural abrasives. The properties of manufactured abrasives can be varied to meet specialized needs. Most of the manufactured abrasives used in 2000 fell into one of the following categories: boron carbide, boron nitride, calcium and magnesium oxides, cerium oxide, chromium oxide, fused aluminum oxides, glass, iron oxides, magnesia, manufactured diamonds, metallic abrasives, porcelains or ceramics (which primarily used zirconium oxides or silicates), precipitated calcium carbonate, silicon carbide, sintered abrasives, sol-gel abrasives, and tin oxide. Manufactured abrasives included in this report are aluminum-zirconium oxide, boron carbide, fused aluminum oxide, metallic abrasives, and silicon carbide. Many of the other abrasives mentioned above are the subject of other U.S. Geological Survey mineral industry surveys. In 2000, the combined Canadian and United States production of abrasive aluminum oxide was estimated to be 90,000 tons with an estimated value of $29.4 million. The combined Canadian and United States production of silicon carbide was estimated to be 45,000 tons with an estimated value of $26.3 million.

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oxide will be sold before 2004 if the current disposal and sales schedules continue.

Production.—The production data for fused aluminum oxide in this report were obtained by the U.S. Geological Survey (USGS) from producers in Canada and the United States. The data were collected from three companies that operated six plants and represented the entire Canadian and United States fused aluminum oxide industry (table 1). Two of the companies operated fused aluminum oxide plants in Canada and the United States. Data from the two countries were combined to protect company proprietary information.

Estimated production of regular-grade fused aluminum oxide in 2000 was 90,000 t with an estimated value of $29.4 million, an increase of about 6% by weight over the 1999 regular-grade fused aluminum oxide production (table 2). Reporting on the output of high-purity fused aluminum oxide has been discontinued to avoid disclosing company proprietary data.

Consumption.—Abrasive-grade fused aluminum oxide has many end uses. Specific applications in 2000 included bonded abrasives (such as abrasive grains that are made to adhere to each other and then are pressed or molded into abrasive tools), coated abrasives (such as abrasive grains glued to a backing of paper or cloth), tumbling media, air or water blasting media, polishing/buffing compounds, and antislip additives. The total value of fused aluminum oxide abrasive grain consumed in the United States was estimated to be $93 million in 2000.

Prices.—The USGS surveyed fused aluminum oxide producers to determine the total value of their production for the year. The survey indicated that the average unit value of regular fused aluminum oxide produced in the United States and Canada during 2000 was $331 per metric ton at the point of production; the average value of high-purity fused aluminum oxide output was $566 per ton at the point of production. Prices of abrasive grain produced from these materials and sold to consumers were significantly higher.

The average price of NDS crude fused aluminum oxide sold by the DOD in 2000 was $232 per ton. The average price of stockpiled fused aluminum oxide grain sold in 2000 was $483 per ton.

Average unit values of fused aluminum oxide trade by the United States in 2000 are based on U.S. Census Bureau customs value data. Average unit values of crude fused aluminum oxide imports during the year ranged from $179 per ton (China) to $447 per ton (Venezuela). Values of fused aluminum oxide grain imports ranged from $268 per ton (China) to $1,371 per ton (Austria). The average value for U.S. exports of fused aluminum oxide during the year was about $2,600 per ton.

Foreign Trade.—During 2000, imports of crude fused aluminum oxide were received from 8 countries and increased by about 21% to 110,000 t valued at $35.2 million compared with those of 1999, and imports of ground and refined fused aluminum oxide were received from 20 countries and increased by 57% to 117,000 t valued at $64.7 million (table 5). Some of the imported crude fused aluminum oxide was refractory-grade material. Canada, China, and Venezuela supplied 44%, 41%, and 15%, respectively, of the crude imports. China, Canada, and Austria provided 37%, 34%, and 9%, respectively, of the ground and refined material.

Compared with 1999 exports of all fused aluminum oxides, 2000 exports remained the same at 9,020 t, but the value of those exports increased to $23.5 million (table 6). Of the exports shipped to 29 countries, 76% went to Canada, Germany, Mexico, and the Netherlands.

Silicon Carbide

Legislation and Government Programs.—As of January 1, 2000, the NDS contained no more silicon carbide. Under congressional authority to dispose all NDS silicon carbide, the DOD sold the last portion of its stockpiled silicon carbide during the first quarter of 1999 (Janet Rollins, Market Analyst, Defense National Stockpile Center, oral commun., 2001). The DOD was not expected to replenish the silicon carbide stockpile.

Production.—Two companies produced abrasive-grade silicon carbide in Canada and the United States during 2000 (table 1). These companies also produced similar amounts of metallurgical-grade silicon carbide. Another company in Hopkinsville, KY, produced a small quantity of silicon carbide, primarily intended for use in heat-resistant products rather than abrasives. Table 2 lists estimated production rounded to avoid disclosing company proprietary information.

Consumption.—Abrasive-grade silicon carbide has many end uses. Specific applications in 2000 included antislip abrasives, blasting abrasives, bonded abrasives, coated abrasives, polishing/buffing compounds, tumbling media, and wiresawing abrasives. The total value of silicon carbide consumed in the United States was estimated to be about $111 million in 2000.

Prices.—The USGS does not collect price data on the various grades of silicon carbide. Based on information from industry sources and publications, however, the average value of abrasive-grade silicon carbide at the point of manufacture was estimated to be about $585 per ton in 2000.

During 2000, imports from China accounted for 82% of total U.S. crude silicon carbide imports and had an average value of $311 per ton; the average value of the remaining 18% of U.S. crude silicon carbide imports was $536 per ton. The average value of silicon carbide grain imports was $1,330 per ton; China accounted for 48% of such imports. The average value of total silicon carbide exports in 2000 was approximately $1,150 per ton.

Foreign Trade.—In 2000, the United States imported crude silicon carbide from 11 countries and imported ground or refined silicon carbide from 22 countries. Imports of crude silicon carbide increased by about 5% during the year to 162,000 t valued at $56.7 million (table 5). Imports of silicon carbide in ground or refined form increased by about 98% to 28,300 t valued at $37.6 million. China accounted for 82% of the crude silicon carbide imports and 48% of the ground or refined silicon carbide. A large part of the Chinese imports, however, reportedly included metallurgical-grade material.

During 2000, the United States exported crude silicon carbide to 15 countries and exported refined or ground silicon carbide to 26 countries. The total value of crude silicon carbide exports for 2000 increased by 13% to $2.78 million from the total value for 1999 (table 6). Compared with 1999 exports of refined or ground silicon carbide, 2000 exports increased by about 7% to 8,810 t valued at $8.71 million. Approximately 72% of the crude exports went to Mexico, and about 82% of the refined or ground material was shipped to Canada.

Aluminum-Zirconium Oxide

During 2000, fused aluminum-zirconium oxide for abrasive

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applications (such as resin-bonded grinding wheels) was produced at two plants in Canada, one belonging to Norton Company (James Chenard, Senior Staff Accountant, Norton Company, oral commun., 2001) and one belonging to Washington Mills Electro Minerals Corp. (Martin Wozniak, Quality Assurance/Manufacturing Services Manager, Washington Mills Electro Minerals Corp., oral commun., 2001). The USGS does not publish aluminum-zirconium oxide production data received from the producers to avoid disclosing company proprietary information.

Boron Carbide

Only one firm, Washington Mills Electro Minerals Corp., was a commercial producer of boron carbide in the United States during 2000 (Martin Wozniak, Quality Assurance/ Manufacturing Services Manager, Washington Mills Electro Minerals Corp., oral commun., 2001). Boron carbide was used for grinding and lapping operations previously possible only with diamond dust; it also was molded to form highly wear-resistant products, such as pressure blast nozzle liners and extrusion dies.

Domestic production data for boron carbide are not reported here to avoid disclosing company proprietary information. The following trade information on boron carbide, however, was available: the United States imported 277 t of boron carbide valued at $6.97 million from 5 countries, primarily Germany, China, and Japan, and exported 28.6 t valued at $481,000 to 12 nations in 2000 (U.S. International Trade Commission, [undated], HTS-2849901000—Customs value by customs value for all countries, accessed July 9, 2001, via URL http://dataweb.usitc.gov/scripts/user_set.asp).

Metallic Abrasives

Production.—Data on U.S. production and shipments of metallic abrasives were based on a survey of domestic producers conducted by the USGS. Survey data were collected from 12 companies operating 14 plants in the United States and accounted for all the domestic industry (table 3).

Steel shot and grit account for almost all metallic abrasives produced domestically (table 4). U.S. production of steel shot and grit in 2000 decreased slightly compared with that of 1999; the average value per ton was $444. Six companies reported production of cut wire shot in 2000, and most of that was cut from carbon steel wire and stainless steel wire. Other products reported included shot cut from aluminum, copper, and zinc wire.

Consumption.—Metal abrasives are used primarily as loose particles propelled at high velocities for blast cleaning or to improve the properties of metal surfaces; approximately 75% of the abrasives are employed in cleaning operations. Principal consumers include foundries, steel manufacturers, machine tool industries, and metalworking plants, particularly those supporting the automotive and aircraft industries.

During 2000, total sales of all steel shot and grit by U.S. producers decreased slightly compared with shipments in the preceding year, and the average value per ton sold or used decreased slightly to $449.

Prices.—The USGS compiles survey data on the value of production and shipments, but it does not collect price data. Values of production and shipments reported by metallic abrasive producers in 2000 are listed in table 4. Values of steel shot and grit were estimated to be from $0.35 to $0.50 per kilogram in 2000. Estimated average values of cut wire shot in 2000 were $3.65 to $5.15 per kilogram for aluminum wire shot and $2.65 to $5.15 per kilogram for stainless steel wire shot.

Average unit values for metallic abrasives traded by the United States during 1999 were as follows: exports averaged $0.64 per kilogram, and imports averaged $0.52 per kilogram.

Foreign Trade.—During 2000, the United States imported metallic abrasives from 18 countries and exported metallic abrasives to 38 countries. Domestic imports increased by about 11% in 2000 to 33,500 t valued at $17.6 million (table 5). About 68% of the imports came from Canada; most of the remaining imports were shipped from the United Kingdom, France, and Germany.

U.S. exports of metallic abrasives increased by about 9% during the year to 28,900 t valued at $18.6 million (table 6). Most of the exports went to Canada; most of the remainder was shipped to Mexico, the United Kingdom, Japan, and Belgium.

Outlook

Economic and technological trends will most likely continue to influence the manufacturing of abrasive materials in the United States. Cheaper imports and higher domestic costs will challenge U.S. producers of fused aluminum oxide and silicon carbide. Competition from developing nations, such as China, will continue to lead to decreases in domestic output. The traditional suppliers among the Western industrialized nations are expected to continue consolidating and contracting.

Metal abrasives markets will continue to be influenced by improved technology in industries that use metallic abrasives. For example, better metal casting methods that achieve near-finish surfaces will reduce demand for some abrasives. Lesser quantities of metallic abrasives will be needed in foundries where new chemical cleaning and finishing techniques are employed.

Emerging suppliers of fused aluminum oxide and silicon carbide in China, Eastern Europe, India, the Republic of Korea, and South America will continue to increase their prominence in world markets. Further success for these suppliers, particularly in such major markets as Japan, the United States, and Western Europe, will depend on their ability to provide higher grades of material and the level of supply reliability while maintaining lower prices. Energy costs, furnace size, quality-control systems, and the availability of essential mineral inputs will be the dominant factors influencing the competitive stance of these suppliers (O'Driscoll, 1997; Zhilun, 1997; Lunghofer and Wolfe, 1998).

Motor vehicle manufacturing will remain a significant indirect influence on demand for manufactured abrasives used by metalworking operations supporting the industry. Curbs on metals consumption by the industry, such as substitution by plastics and newer lighter weight designs of automobiles, are important factors to be considered in long-range demand forecasts for manufactured abrasives.

References Cited

Lunghofer, E.P., and Wolfe, L.A., 1998, Fused minerals—Where are they heading?: Industrial Minerals, no. 364, September, p. 19-25.

O'Driscoll, Mike, 1997, Silicon carbide—Supply sector showdown: Industrial Minerals, no. 352, January, p. 19-27.

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Wellborn, W.W., 1996, Abrasives—Synthetics cut natural products down to size: Industrial Minerals, no. 347, August, p. 31-45.
Zhilun, Yuan, 1997, Chinese bauxite and fused alumina—Exports spark EC debate: Industrial Minerals, no. 360, September, p. 93-99.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Abrasives. Ch. in United States Mineral Resources, Professional Paper 820, 1993.

Abrasives, manufactured. Ch. in Mineral Commodity Summaries, annual.

Abrasives, manufactured. Mineral Industry Surveys, quarterly.

Other

Abrasives, Industry & Trade Summary. U.S. International Trade Commission, May 1995.

Industrial Minerals (monthly).

European Abrasives Directory 1997-98.

TABLE 1
CRUDE ARTIFICIAL ABRASIVES MANUFACTURERS IN 2000

Company	Location	Product
The Exolon-Esk Company	Hennepin, IL	Silicon carbide.
Do.	Thorold, Ontario, Canada	Fused aluminum oxide (regular).
Norton Company	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Worcester, MA	General abrasive processing.
Do.	Chippewa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do.	Shawinigan, Quebec, Canada	Silicon carbide.
Washington Mills Electro Minerals Corp.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Do.	Niagara Falls, NY	Fused aluminum oxide (high-purity).
Washington Mills Ltd.	do.	Fused aluminum oxide (regular).

TABLE 2
PRODUCTION OF CRUDE SILICON CARBIDE AND FUSED ALUMINUM OXIDE IN THE UNITED STATES AND CANADA 1/

	1999 r/			2000		
Product	Quantity e/ 2/ 3/ (metric tons)	Value e/ 2/ (thousands)	Yearend stocks (metric tons)	Quantity e/ 2/ 3/ (metric tons)	Value e/ 2/ (thousands)	Yearend stocks (metric tons)
Silicon carbide 4/	65,000	$38,500	W	45,000	$26,300	W
Aluminum oxide, regular, abrasives 5/	85,000	29,000	W	90,000	29,400	W

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to no more than three significant digits.

2/ Due to rounding, does not match total quarterly Mineral Industry Survey estimated data.

3/ Quantities are rounded to the nearest 5,000 tons to avoid disclosing proprietary data.

4/ Approximately one-half of the quantity and value consists of material for metallurgical and other nonabrasive applications.

5/ Regular grade normally accounts for about 85% of total output, and high-purity material accounts for the remainder.

TABLE 3
U.S. PRODUCERS OF METALLIC ABRASIVES IN 2000

Company	Location	Product (shot and/or grit)
Chesapeake Specialty Products	Baltimore, MD	Steel.
Ervin Industries, Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Do.	do.	Do.
Frohn North America, Inc.	Austell, GA	Cut wire.
Marwas Steel Co.	Scottdale, PA	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Steel.
National Metal Abrasive Inc.	Wadsworth, OH	Do.
Peerless Metal Powders & Abrasive	Detroit, MI	Do.
Pellets, Inc.	Tonawanda, NY	Cut wire.
The Platt Brothers, Inc.	Waterbury, CT	Do.
Premier Shot Co.	Cleveland, OH	Do.
U.S. Filter Abrasive Materials	Hillsdale, MI	Cut wire, steel.
Wheelabrator Abrasives, Inc.	Bedford, VA	Steel.

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TABLE 4
ANNUAL PRODUCTION AND SHIPMENTS FOR METALLIC ABRASIVES IN THE UNITED STATES, BY PRODUCT 1/

Product	Production		Shipments 2/	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:				
Steel shot and grit	278,000	$122,000	282,000	$122,000
Cut wire shot and other e/	2,010	7,150	2,010	7,170
Total	280,000	129,000	284,000	130,000
2000:				
Steel shot and grit	266,000	118,000	270,000	121,000
Cut wire shot and other e/	2,140	7,120	2,130	7,120
Total	269,000	125,000	272,000	128,000

e/ Estimated.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes reported exports.

TABLE 5
U.S. IMPORTS OF ALUMINUM OXIDE AND SILICON CARBIDE, BY COUNTRY AND TYPE 1/

Country	1999		2000	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Crude aluminum oxide:				
Canada	55,600	$22,400	48,800	$19,700
China	31,200	6,800	45,200	8,080
Russia	1,320	638	5 3/	24 3/
Venezuela	2,600	1,470	16,200	7,240
Other	566	249	169	117
Total	91,400	31,500	110,000	35,200
Ground and refined aluminum oxide:				
Austria	8,910	12,200	10,000	13,700
Brazil	6,900	4,850	7,530	5,400
Canada	22,500	8,390	39,900	14,300
China	23,600	6,440	43,500	11,600
France	1,660	2,290	2,890	3,310
Germany	7,380	8,640	8,150	10,400
Italy	1,210	1,140	1,860	1,720
Slovenia	1,110	699	1,290	696
Other	1,130	2,380	1,730	3,520
Total	74,400	47,000	117,000	64,700
Crude silicon carbide:				
Canada	27,100	17,800	15,600	9,280
China	123,000	33,200	133,000	41,500
Russia	3,960	1,690	4,510	2,000
Venezuela	616	282	251	108
Other	523	635	7,980	3,830
Total	155,000	53,600	162,000	56,700
Ground and refined silicon carbide:				
Brazil	2,300	1,840	5,420	3,440
Canada	247	78	296	205
China	3,490	2,540	13,500	8,230
Germany	1,470	5,630	1,930	6,110
Japan	1,250	7,570	1,750	10,400
Norway	2,600	5,890	2,830	6,980
Mexico	347	383	382	431
Russia	2,070	839	1,440	477
Other	473	1,130	769	1,290
Total	14,200	25,900	28,300	37,600

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS OF ALUMINUM OXIDE AND SILICON CARBIDE, BY COUNTRY AND TYPE 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Metallic abrasives:				
Canada	24,900	$10,200	22,900	$10,300
France	846	317	2,760	2,690
Germany	1,240	2,250	1,560	1,070
Japan	339	586	451	770
United Kingdom	1,730	1,140	2,520	1,090
Other	995	628	3,330	1,600
Total	30,100	15,200	33,500	17,600

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ All or part of these data have been referred to the U.S. Census Bureau for verification.

Source: U.S. Census Bureau.

TABLE 6
U.S. EXPORTS OF ALUMINUM OXIDE, SILICON CARBIDE, AND METALLIC ABRASIVES, BY COUNTRY AND TYPE 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Crude aluminum oxide:				
Canada	1,960	$2,490	2,080	$2,660
Germany	1,950	7,510	2,160	7,390
Mexico	2,280	2,020	1,680	2,070
Netherlands	883	603	905	830
Other	1,950	7,770	2,200	10,600
Total	9,020	20,400	9,020	23,500
Crude silicon carbide:				
Japan	58	954	187	834
Mexico	131	471	871	1,290
Sweden	32	11	79	29
Other	77	1,020	69	627
Total	299	2,460	1,210	2,780
Ground and refined silicon carbide:				
Canada	6,800	5,500	7,260	4,660
Japan	236	998	318	2,160
Mexico	690	691	750	737
Other	530	1,280	483	1,150
Total	8,260	8,470	8,810	8,710
Metallic abrasives:				
Belgium	631	233	551	197
Canada	14,600	6,090	16,000	6,750
Japan	498	460	1,040	531
Mexico	7,350	6,520	8,820	7,360
United Kingdom	2,490	2,610	1,040	1,350
Other	1,010	1,970	1,400	2,450
Total	26,600	17,900	28,900	18,600

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.

Source: U.S. Census Bureau.

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ALUMINUM

By Patricia A. Plunkert

Domestic survey data and tables were prepared by Micheal George, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In 2000, 12 domestic companies operated 23 primary aluminum reduction plants that produced almost 3.7 million metric tons (Mt) of metal. Montana, Oregon, and Washington accounted for 36% of the production; Maryland, New York, Ohio, and West Virginia, 22%; and other States, 42%. The value was estimated to be $6 billion.

Increased energy costs, particularly in the Pacific Northwest, led several aluminum smelters to reduce production capacity during the latter half of the year. By yearend, a total of 729,000 tons per year (t/yr) of primary smelter capacity had been closed, about 45% of the 1.62 million tons per year (Mt/yr) of engineered capacity for the 10 smelters operating in the region.

Aluminum recovered from purchased scrap decreased by 7% to 3.45 Mt. Of this recovered metal, 60% came from new (manufacturing) scrap and 40% from old (discarded aluminum products) scrap. Aluminum used beverage can (UBC) scrap accounted for more than one-half of the reported old scrap consumption in 2000. The recycling rate for aluminum UBCs remained relatively stable at 62.1%.

The transportation and the container and packaging industries remained the largest domestic markets for aluminum products in 2000. The transportation industry accounted for 37% of domestic consumption; containers and packaging, 23%; building and construction, 15%; consumer durables, 8%; electrical, 8%; and other uses, 9%.

U.S. imports for consumption decreased in 2000 compared with those of 1999, reversing a 3-year upward trend that began in 1997. Canada remained the largest shipper of aluminum materials to the United States, followed by Russia. Total exports from the United States increased 7% in 2000.

The price of primary ingot on the domestic and the international markets fluctuated during the year. The 2000 monthly average domestic price decreased by almost 6 cents per pound from January to December. The annual average, however, increased compared with that of the previous year.

At the end of 2000, world inventories, as reported by the International Aluminium Institute (IAI), decreased slightly compared with those of 1999. Inventories of primary metal held by the London Metal Exchange Ltd. (LME) decreased dramatically, whereas inventories of aluminum alloy increased.

Primary aluminum was produced in 43 countries in 2000. The United States remained the largest producer with 15% of the world total, followed by Russia with 14%, China with an estimated 11%, and Canada with 10%. World primary metal production increased by about 2% compared with that of 1999.

Production

Primary.—Domestic primary aluminum production, which totaled a reported 3,668,438 metric tons (t), decreased by 3% compared with that of 1999 (table 1). Production data were obtained from the 12 domestic producers, all of whom responded to the request from the U.S. Geological Survey (USGS) for data.

On May 3, 2000, Alcoa Inc. and Reynolds Metals Co. announced that the U.S. Department of Justice (DOJ) and the European Union (EU) had approved their proposed merger and that the merger had been completed. Reynolds shareholders had

Aluminum in the 20th Century

Aluminum is the second most abundant metallic element in the earth's crust after silicon, yet it is a comparatively new industrial metal that has been produced in commercial quantities for just over 100 years. In April 1886, a formal patent application was filed that permitted, for the first time, the mass commercial production of aluminum. In 1900, the Pittsburgh Reduction Company (Alcoa Inc.) was the sole domestic producer of primary aluminum metal, and production had grown to 3,244 metric tons (7.15 million pounds) from 83 pounds in 1883. World production in 1900 totaled 7,339 tons and took place at nine reduction plants owned by six companies in four countries. The United States was the leading producer, followed by Switzerland (2,500 tons), France (1,026 tons), and the United Kingdom (569 tons). The metal was used mainly as a substitute for copper in the transmission of electricity and for culinary articles, machinery parts, special alloys, explosives, paint, and as a substitute for stone and zinc in lithographic work.

In 2000, the United States remained the world's largest producer and consumer of aluminum; however, its dominance in the industry had eroded over the last 40 years of the century. At the close of World War II, domestic primary aluminum production accounted for over 40% of the world's production. In 2000, primary aluminum was produced in 43 countries, and the United States accounted for only about 15% of the 24 million tons of production. Since the inception of the aluminum industry, metal has been recovered from scrap and its importance as a source of aluminum supply continues to grow. In 2000, metal recovered from scrap accounted for about 35% of the domestic supply of aluminum. Energy costs and concerns over waste management will continue to provide the impetus for increased recycling rates. Today, aluminum is used in a wide range of applications, such as automobiles, airplanes, buildings, tools, appliances, packaging, electrical systems, and countless other components of everyday life. Measured either in quantity or value, aluminum's use exceeds that of any other metal except steel, and it is important in virtually all segments of the world economy.

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approved the merger on February 11. Under the terms of the consent decree entered into with the DOJ and an undertaking agreement with the EU, Alcoa was forced to sell a 25% interest in Reynolds' Longview, WA, smelter, as well as Reynolds' interests in three alumina refineries—Worsley, Australia (56%); Stade, Germany (50%); and Sherwin, TX (100%). As a result of the merger, each outstanding share of Reynolds common stock was converted into 1.06 shares of Alcoa common stock (Alcoa Inc., 2000g).

On June 1, Alcan Aluminium Ltd. and algroup, the aluminum division of Alusuisse Lonza Group Inc., announced that, following the approval of the DOJ and the EU, the companies had reached agreement on their merger plan (Alcan Aluminium Ltd., 2000a). The EU gave its approval subject to commitments made by the companies to alleviate the EU's competition concerns in the aluminium trihydrate (ATH) market. Among its commitments, Alcan proposed selling algroup's ATH facility in Martinswerk, Germany, and the algroup lithography operations in Bridgenorth, United Kingdom (Platt's Metals Week, 2000j). The merger, which involved the combination of a cash payment and the exchange of 17.1 Alcan common shares for every algroup share, was finalized on October 17 (Alcan Aluminium Ltd., 2000h).

Increased energy costs, particularly in the Pacific Northwest, led several aluminum smelters to reduce production capacity during the latter half of the year. By yearend, a total of 729,000 t/yr of primary smelter capacity had been closed, about 45% of the 1.62 Mt/yr of engineered capacity for the 10 smelters operating in the region. Columbia Falls Aluminum Co. had idled two and one-half of its five potlines at its 168,000-t/yr Columbia Falls, MT, smelter and temporarily reduced production capacity by 84,000 t/yr (Metal Bulletin, 2000i). Northwest Aluminum Corp. closed its 82,000-t/yr smelter in The Dalles, OR (Metal Bulletin, 2000j). Goldendale Aluminum Co. idled all but 25,000 t/yr of capacity at its 168,000-t/yr smelter in Goldendale, WA (Metal Bulletin, 2000j). Kaiser Aluminum & Chemical Corp. closed its 73,000-t/yr Tacoma, WA, smelter and idled 110,000 t/yr of capacity at its 200,000-t/yr smelter in Spokane (Mead), WA (Kaiser Aluminum & Chemical Corp., 2000b). Alcoa temporarily idled its 121,000-t/yr smelter in Troutdale, OR (Alcoa Inc., 2000j), and Vanalco Inc. idled its 116,000-t/yr smelter in Vancouver, WA (Metal Bulletin, 2000v).

In June, Ormet Primary Aluminum Corp. temporarily closed two potlines at its 257,000-t/yr smelter in Hannibal, OH, resulting in a loss of 7,000 metric tons per month (t/mo) of aluminum metal production. The decision to close was based on low aluminum prices, higher than usual alumina prices, and higher electrical energy prices in the peak summer months. During the closure, the company sold its excess alumina and electricity (Ormet Primary Aluminum Corp., 2000b). In August, Ormet announced the restart of the two idled potlines, which were back in operation by the end of September (Ormet Primary Aluminum Corp., 2000a).

Alcan restarted 60,000 t/yr of capacity at its 186,000-t/yr primary aluminum smelter in Sebree, KY, to meet increased customer demand and to compensate for smelter closures in Canada and the United Kingdom. The restart was completed by yearend (Alcan Aluminium Ltd., 2000f).

In January, Alcoa announced plans to restart 200,000 t/yr of primary aluminum smelter capacity by the end of the year. The restarts would be spread over the 450,000-t/yr of capacity that had been idled since 1994 and was expected to involve low-cost, operating smelters in the United States and Australia (Alcoa Inc., 2000k).

Alcoa and Michigan Avenue Partners (MAP) announced that they had reached an agreement whereby MAP would acquire the 204,000-t/yr aluminum smelter in Longview, WA. Alcoa was required to sell 25% of Longview as a condition of the EU approval of the Alcoa/Reynolds merger, but Alcoa accepted MAP's offer to purchase the entire operation. MAP is a Chicago investment group. One of its affiliates, McCook Metals L.L.C. is the second largest aluminum plate company in North America and produces specialty products for aircraft, aerospace, and defense industries. The sale was contingent on financing and regulatory approval (Alcoa Inc., 2000m).

Century Aluminum Co. purchased Xstrata AG's 23% interest in the 215,000-t/yr Mount Holly, SC, primary aluminum smelter. The $95 million purchases increased Century Aluminum's interest in the smelter to 49.67%. Alcoa, which owned 50.33% of the smelter, will continue to operate and manage the facility (Regan, 2000a).

Century Aluminum and Southwire Co. reached a definitive agreement for the purchase of Southwire's 237,000-t/yr smelter in Hawesville, KY. Completion of the $468 million transaction was subject to the completion of a labor agreement, arrangement of financing, and the receipt of regulatory approvals (Southwire Co., 2000).

Noranda Aluminum Inc. commissioned its new single-piece anode process at its 222,000-t/yr aluminum smelter in New Madrid, MO. Completion of the $72 million expansion, which was expected by mid-2002, will increase production capacity at the smelter by 15% to 253,000 t/yr (Platt's Metals Week, 2000o).

Alcan revealed plans for a $22 million capital project to expand extrusion billet production at its Sebree, KY, aluminum smelter by 65,000 t/yr. The project, which was begun in August and would require approximately 20 months to complete, involved engineering work and construction of an ultrasonic billet inspection station, a new continuous homogenization furnace, as well as an automated billet sawing and stacking system (Alcan Aluminium Ltd., 2000c).

Ormet announced that it planned to curtail carbon anode operations at its Hannibal smelter by the end of September 2001. The company reported that the closure was primarily in response to the Maximum Achievable Control Technology requirements, as established under the provisions of the Clean Air Act, that were due to take effect at their smelter in October 2001. Ormet's decision not to modernize the facility to meet the new environmental standards was owing to the age and configuration of the facility and the potential development of advanced technology. The company was negotiating with outside suppliers for the purchase of its 170,000-t/yr carbon anode requirement. The purchased anodes, which would be larger than those produced by Ormet, reportedly would allow increased metal production without the consumption of additional power (Ormet Primary Aluminum Corp., 2000c).

In May, members of United Steelworkers of America (USWA) Local 5724, which represents 1,200 employees at Ormet's Hannibal, OH, smelter, ratified a new labor agreement. Terms of the contract, which was set to expire at the end of August 2003, were not disclosed (Regan, 2000b).

Century Aluminum and the USWA reached agreement on a new 5-year labor contract at the Hawesville, KY, primary

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aluminum smelter. Terms of the agreement, which will become effective upon completion of the purchase of the smelter, were not disclosed (Metal Bulletin, 2000h).

A labor dispute between the USWA and Kaiser, which began in September 1998, officially ended on September 18 when an arbitration panel ruled on a half-dozen unresolved issues that were blocking completion of a new contract. The new contract runs through September 30, 2005, calls for a 2.6% average annual increase in the overall wage and benefit package, and reduces the total number of hourly jobs by approximately 19% at the five plants covered by the contract (Kaiser Aluminum & Chemical Corp., 2000a).

MAP and USWA ratified a new 5-year labor contract covering workers at the Scottsboro, AL, rolling mill. The contract included increases in wages, pensions, retiree medical benefits, and enhanced opportunities to share in productivity gains. The mill produces about 136,000 t/yr (300 million pounds per year) of mill-finished and painted sheet products (Metal Bulletin, 2000t).

Alcan announced that it was investing $15 million at its Terre Haute, IN, light gauge rolling facility. The project, which ultimately would increase the plant's capacity by about 22,700 t/yr (50 million pounds per year), included a wide foil mill with doubling capability to complement existing rolling equipment. The facility produces light gauge aluminum fin and foil products (Alcan Aluminium Ltd., 2000g).

Kaiser completed the sale of its Micromill® assets and patented technology to Alcoa for an undisclosed price. The Micromill process is a continuous casting technology developed by Kaiser in the early 1990s, which was designed to convert molten metal into aluminum sheet in a single continuous step. The prototype plant built in Reno, NV, a key element of the sale to Alcoa along with all patent rights to the technology, was designed to produce 41,000 t/yr (90 million pounds per year) of flat rolled aluminum (Metal Bulletin, 2000c).

Commonwealth Industries Inc. announced that its subsidiary, Commonwealth Aluminum Corp., signed a 10-year guaranteed supply agreement with Glencore Ltd. for the purchase of primary aluminum. Commonwealth agreed to purchase a minimum of 544,000 t (1.2 billion pounds) of aluminum beginning January 1, 2001. This purchase will fill only part of Commonwealth's metal requirements for its fabrication facilities. Commonwealth Aluminum is a large recycler of aluminum, and more than one-half of its raw material comes from scrap (Commonwealth Industries Inc., 2000).

McCook Metals, a subsidiary of MAP, entered the aluminum extrusion market. The company began casting 2000, 6000, and 7000 series extrusion billets at its rolling mill in McCook, IL. Depending on the alloy, the plant uses scrap and/or primary metal to make the billets (Platt's Metals Week, 2000l).

Norsk Hydro ASA purchased Wells Aluminum Corp., a major U.S. extrusion company based in Baltimore, MD. The acquisition will increase Hydro's extrusion capacity by 75,000 t/yr and, according to the company, will make it the fourth largest extrusion company in the United States with a potential sales volume of 110,000 t/yr. Wells was a custom extruder, finisher, and fabricator of soft alloy aluminum products principally serving the building and construction, transportation, consumer durables, and electrical markets. Wells had a network of 7 facilities with 12 extrusion presses in 6 Midwestern and Southeastern States plus its own casting facility for extrusion billet (Norsk Hydro ASA, 2000b).

Alcoa purchased Excel Extrusions Inc., a subsidiary of Noranda Aluminum Inc. Excel's plant in Warren, OH, has the capacity to produce about 16,000 t/yr (35 million pounds per year) of soft alloy aluminum extrusions, which are used primarily in the building and construction industries. The plant also has a vertical paint line with a capacity to coat about 11,000 t/yr (24 million pounds per year) of extrusions (Alcoa Inc., 2000h).

Butler Manufacturing Co. announced plans to build a new aluminum extrusion and finishing plant in Greeneville, TN, for its Vistawall Architectural Products division, a manufacturer of engineered windows, curtain walls, storefront and skylight systems for the nonresidential building construction market (Butler Manufacturing Co., 2000). The plant initially will add 9,000 t/yr (20 million pounds per year) of capacity, increasing the company's extrusion capacity by 50% (Platt's Metals Week, 2000f).

Indalex Aluminum Solutions Group, a subsidiary of Caradon plc of the United Kingdom, underwent some major changes during the year. Indalex acquired the aluminum extrusion and billet casting operations of Columbia Pacific Aluminum Corp., a subsidiary of Columbia Ventures Corp. The purchase included casting plants in City of Industry, CA, and Rockwall, TX, as well as three extrusion plants in California—Modesto, Watsonville, and City of Industry (Platt's Metals Week, 2000h). Indalex closed two of its older extrusion facilities in Dolton, IL, and Winton, NC (Platt's Metals Week, 2000k). The company also launched several expansion plans. Indalex announced plans to build a new 79,000-t/yr (175-million-pound-per-year) casting facility in Toronto, Canada. The plant will become part of Indalloy, the casting division of Indalex (Indalex Aluminum Solutions Group, 2000b). Expansion plans for existing facilities were also announced. Indalex planned to invest $42 million during 2001 to improve and expand its facilities in Gainesville, GA; Elkhart, IN; and Toronto, Canada (Indalex Aluminum Solutions Group, 2000a).

Quanex Corp. purchased Temroc Metals Inc., an aluminum extrusion and fabrication company based in Hamel, MN, which produced customized aluminum extrusions and fabricated metal products for recreational vehicles, architectural products, electronics, and other markets (American Metal Market, 2000f).

Alcoa announced plans to begin construction of a new cast aluminum rod production facility in early 2001. The facility will produce cast rod in sizes tailored to forged and impact-extruded applications in the automotive, industrial, and consumer markets, and will increase the availability of standard and special rod and bar, standard and custom profiles, seamless and structural pipe and tube, and drawn seamless tube (Alcoa Inc., 2000i).

Alcoa acquired Cordant Technologies Inc. Cordant was composed of three business units: Howmet Castings, a supplier of investment cast superalloy and titanium components used in jet aircraft and electrical power generation; Huck Fasteners, a designer and manufacturer of high-performance fasteners and fastening systems; and Thiokol Propulsions, a supplier of solid rocket propulsion systems. Cordant had approximately 17,000 employees worldwide at some 58 facilities in Canada, France, Japan, the United Kingdom, and the United States (Alcoa Inc., 2000e). With the purchase of Cordant, Alcoa acquired 84.7% of Howmet International Inc. By the end of June, Alcoa had purchased all of the outstanding shares of Howmet and became the company's sole owner (Alcoa Inc., 2000f).

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Alcoa also purchased the assets of privately held C-KOE Aluminum Inc. of Dallas, TX. C-KOE Aluminum produced primary grade aluminum particle ingot for the chemicals and metals markets (Alcoa Inc., 2000b).

Secondary.—Metal recovered from new and old scrap decreased to 3.45 Mt in 2000 (table 3), according to data derived by the USGS from its "Aluminum Scrap" survey. Of the 78 companies and/or plants to which monthly or annual survey requests were sent, 57 responded, which represented 91% of the total scrap consumed, as listed in table 4.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute and the Institute of Scrap Recycling Industries Inc., 62.6 billion aluminum UBCs were recycled in the United States in 2000, for a beverage can recycling rate of 62.1% or nearly two of every three aluminum cans shipped. Although the recycling rate was slightly lower than the 1999 rate of 62.5%, this was the 12th consecutive year that the U.S. recycling rate exceeded 60%. According to the organizations, the average aluminum beverage can produced domestically is comprised of more than 51% recycled content (Aluminum Association Inc., 2001a).

Superior Aluminum Alloys installed a third furnace at its New Haven, IN, facility increasing the plant's capacity by 42%. The plant's capacity will increase to about 8,000 t/mo (17 million to 18 million pounds per month) or more than 90,000 t/yr. The company also installed an automatic sow-casting system, which will enable it to pour up to one sow per minute (Platt's Metals Week, 2000p).

Behr Metals, a subsidiary of Joseph Behr & Sons, also installed a new furnace at its facility that doubled the plant's smelting capacity. A new 102-t (225,000-pound) furnace was installed at the company's Rockford, IL, plant and was expected to produce about 3,000 t (7 million pounds) of metal per month (Metal Bulletin, 2000f).

Alcan's extrusion scrap recycling facility in Sebree, KY, started up during the latter half of the year. The feed for this plant was expected to be new extrusion scrap, most of which would be generated by Alcan's customers. The furnace has an capacity of 50,000 t/yr (Platt's Metals Week, 2000b).

In October, Norsk Hydro's new remelt plant in Henderson, KY, came on-stream with an initial capacity of 90,000 t/yr of extrusions. The plant will recycle aluminum scrap into primary quality aluminum extrusion billets (Norsk Hydro ASA, 2001a, p. 21).

Wabash Alloys LLC closed 25% of its capacity at its East Syracuse, NY, plant. Prior to the cutback, the plant had a capacity of about 7,000 t/mo (15 million pounds per month) (Worden, 2000c).

Huron Valley Steel Corp. closed its 27,000-t/yr (60-million-pound-per-year) River Rouge, MI, smelter. The facility, known as Fritz Products, produced specification ingot, such as A380.1, from shredded aluminum scrap provided by Huron Valley. In lieu of operating the smelter, the company will concentrate on improving the quality of and expanding the markets for shredded aluminum products based on recent improvement in their aluminum particle sorting technologies. Longer-term plans called for upgrading and reopening the River Rouge smelter (Worden, 2000c).

Keystone Aluminum Inc. reportedly closed its secondary smelter in Mars, PA. The plant produced aluminum deox for the steel industry (Worden, 2000a).

In December, Alchem Aluminum Inc., a wholly owned subsidiary of IMCO Recycling Inc., began operations at its new 91,000-t/yr smelter in Saginaw County, MI, that will supply General Motors Corp. (GM) with more than 900,000 t (2 billion pounds) of specification aluminum alloys over a 13-year period. All of the production from this plant will be delivered in molten form to GM's Saginaw metal casting operation to manufacture engine components (IMCO Recycling Inc., 2001a, p. 3, 6).

Quanex purchased a continuous cast rolling mill in Ft. Lupton, CO, from Alcoa. In August 1999, Alcoa purchased the Ft. Lupton and the San Antonio, TX, rolling mills from ACX Technologies Inc. Both of the plants converted UBCs to can sheet. Upon reviewing the Alcoa purchase, the DOJ determined that the acquisition of the Ft. Lupton facility would likely lessen competition in the manufacture and sale of can lid stock since Alcoa controlled 50% of the North American market and Ft. Lupton was one of only five other North American producers. Therefore, to avoid antitrust violations, Alcoa was required to sell the facility and upon its purchase, Quanex was required to continue to operate the plant in the manufacture and sale of can lid stock (Platt's Metals Week, 2000m).

IMCO closed its Sikeston, MO, and Bedford, IN, aluminum recycling plants. The material processed at these plants will be handled at other IMCO facilities and most of the plants' equipment will be sent to other plants (IMCO Recycling Inc., 2000). The closure of the Bedford and Sikeston plants reportedly reduced IMCO's domestic annual capacity by about 10% or 122,000 t (270 million pounds) (IMCO Recycling Inc., 2001b). IMCO also temporarily closed its Wendover, UT, plant that normally recycled aluminum dross (IMCO Recycling Inc., 2001a, p. 8).

Consumption

In 2000, the transportation industry accounted for slightly more than 3.6 Mt of total U.S. shipments of aluminum products (table 6). Shipments to the container and packaging industry, which was the second largest domestic end-use market, continued to decline and was less than 2.3 Mt. Total shipments of aluminum products to domestic users in 2000 was at the same level as that of 1999.

The Partnership for a New Generation of Vehicles (PNGV), initiated in 1993, represents a historic and unprecedented collaboration among teams of scientists and engineers from the U.S. automotive industry, the Federal Government, and academia. One of the goals of the PNGV is the development of family car prototypes that will get nearly three times the Corporate Average Fuel Economy (CAFE) Federal regulatory requirement of 27.5 miles per gallon. At the North American International Auto Show, held in January, Ford Motor Co. and GM introduced their prototypes to the public. Both the GM Prodigy and the Ford Precept were reported to be aluminum intensive vehicles that would use aluminum for the frame and body panels (Wrigley, 2000d). Meanwhile, the use of aluminum in the typical family vehicle continued to grow from 75 kilograms (kg) (166 pounds) in 1991 to more than 111 kg (245 pounds) in 2000 (Wrigley, 2000f).

DaimlerChrysler Corp. announced that it planned to purchase the major components for its new cross-mounted V-6 engines from Nemak SA, Monterrey, Mexico. When engine production begins in 2002, the block and head castings are expected to use more than 14,000 t (31 million pounds) of recycled aluminum annually (Wrigley, 2000g). Later in the year, GM announced

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that it would purchase, on an annual basis, aluminum cylinder head castings from Nemak for up to 350,000 of its Gen III Vortec V-8 truck engines. Nemak's 7,300 t/yr (16 million pounds per year) of head castings would supplement the castings already being provided by GM's own casting operations in Saginaw, MI, and Castech SA's facilities in Saltillo, Mexico (Wrigley, 2000c).

Ford opened a new aluminum casting plant in Brook Park, OH, to produce engine blocks for its new 2.3 liter, in-line four-cylinder engine. Initial production at the plant was expected to be about 110,000 aluminum engine blocks per year. Precision sand casting will be used to produce the engine blocks (Wrigley, 2000b). In November, Ford and Nemak signed an agreement giving Nemak control of Ford's two big aluminum parts-casting plants in Ontario, Canada, the Windsor Aluminum Plant and the Essex Aluminum Plant. These two plants consume enough secondary aluminum alloy to produce an estimated 81,600 t (180 million pounds) of engine castings each year (Wrigley, 2000a).

Alcan and Ford signed a multiyear aluminum supply agreement. Alcan will provide metal in various forms, including foundry ingot for cast products and flat-rolled autobody sheet for Ford's stamping plants. Alcan will also provide design and technology support services, and Ford will purchase minimum monthly volumes of metal with options for additional amounts as required (Alcan Aluminium Ltd., 2000b).

Anticipating a major increase for aluminium suspension system components in the automotive market, Hayes Lemmerz International Inc. announced plans to build a new foundry in Montague, MI. The plant reportedly would use primary aluminum casting alloys to produce control arms, knuckles, crossmembers, and other components for the North American automotive industry (Wrigley, 2000e).

Pechiney sold its remaining interest in American National Can Group (ANC) to Rexam plc of the United Kingdom. With can plants elsewhere in Europe, the addition of ANC's 38 billion beverage cans per year gives Rexam an annual canmaking capacity of 45 billion cans and makes the company the world's largest can manufacturer (Metal Bulletin, 2000q).

Ball Corp., a metal and plastic packaging supplier, announced several plant closures during the year. Ball's Salisbury, NC, aluminum beverage can plant, which had the capacity to produce about 1 billion cans per year, was closed during the third quarter. Ball also announced that it had halted a previous owner's plans to install a beverage can line in a plant in China and had written off a 10% stake in a Russian beverage can joint venture (Platt's Metals Week, 2000d). Ball closed a two-piece aluminum beverage can manufacturing line at its Richmond, British Columbia, plant, and a metal coating and sheeting operation at its Hamilton, Ontario, facility was expected to close by March 2001 (American Metal Market, 2000c).

Crown Cork & Seal reported the reorganization of its U.S. metal packaging units from a single business unit into three divisions—beverage cans, food cans, and aerosol cans. The breakup would give the company the flexibility to sell or joint venture the individual divisions (Platt's Metals Week, 2000i).

Stocks

Domestic inventories of aluminum ingot, mill products, and scrap decreased to 1.55 Mt at yearend 2000 from 1.87 Mt at yearend 1999 (Aluminum Association Inc., 2001b). The LME reported that primary aluminum metal ingot at its U.S. warehouses decreased dramatically to 125 t at yearend 2000 from 12,700 t at yearend 1999. The LME also reported that at yearend 2000 its U.S. warehouses did not hold any stocks of aluminum alloy ingot compared with 860 t at yearend 1999 (London Metal Exchange Ltd., 2000).

Prices

The monthly average U.S. market price of primary aluminum metal, as reported by Platt's Metals Week, fluctuated throughout the year. The monthly average price began the year at 80.1 cents per pound and, by December, had fallen to 74.3 cents per pound. However, the average price for the year increased from 65.7 cents per pound in 1999 to 74.6 cents per pound in 2000.

The LME cash price for high-grade primary aluminum ingot followed the same general trend as the U.S. market price. The 2000 average annual LME cash price was 70.3 cents per pound.

In May 1999, the Commodity Exchange (COMEX) division of the New York Mercantile Exchange (NYMEX) launched an aluminum futures contract for primary aluminum ingot. During its first full year of trading, the average monthly spot settlement price followed the trend of both the U.S. market and LME prices. The monthly average, based on a rolling average of the daily spot settlement price, declined from 80.3 cents per pound in January to 74.6 cents per pound in December.

Purchase prices for aluminum scrap, as quoted by American Metal Market, also fluctuated during the year but closed at lower levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 47.5 to 48.5 cents per pound; old sheet and cast aluminum, 38.5 to 39.5 cents per pound; and clean, dry aluminum turnings, 40 to 41 cents per pound.

Aluminum producers' buying price range for processed and delivered UBCs, as quoted by American Metal Market, also closed lower at yearend. The price range began the year at 57 to 59 cents per pound and closed the year at 53 to 54 cents per pound. Resource Recycling published a monthly transaction price for aluminum UBCs in its Container Recycling Report. During the year, the monthly average decreased significantly from 62.9 cents per pound in January to 53.9 cents per pound in December. However, similar to the U.S. market price trend of primary aluminum ingot, the annual average price for aluminum UBCs in 2000 of 57.7 cents per pound was higher than the 1999 annual average of 50.6 cents per pound.

The yearend indicator prices for selected secondary aluminum ingots, as published in American Metal Market, also decreased significantly compared with those of 1999. The closing prices for 2000 were as follows: alloy 380 (1% zinc content), 68.7 cents per pound; alloy 360 (0.6% copper content), 74.1 cents per pound; alloy 413 (0.6% copper content), 73.8 cents per pound; and alloy 319, 72.7 cents per pound. Platt's Metals Week published an annual average U.S. price of 65.6 cents per pound for A-380 alloy (3% zinc content). The average LME cash price for a similar 380 alloy was 55.2 cents per pound.

Trade

Total exports of aluminum materials from the United States increased 7% in 2000 compared with those of 1999 (table 8).

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Exports of semifabricated material and scrap increased but exports of crude metals and alloys decreased compared with those of 1999 (table 9). About two-thirds of total U.S. exports were accounted for by Canada and Mexico.

Imports for consumption decreased in 2000 compared with those of 1999, reversing a 3-year upward trend that began in 1997 (table 10). Canada remained the major source country by supplying 55% of the total imports in 2000 (table 11). Russia continued to be the second largest supplier of aluminum materials. The decline in imports of crude metal and alloys from Russia was more than compensated for by increased imports of semifabricated materials and scrap.

World Review

Despite the temporary closure of production capacity in the Pacific Northwest region of the United States, world production of primary aluminum metal increased by 2% in 2000 compared with that of 1999 (table 12). Production increased owing in part to the opening of new smelters in Canada and Mozambique. U.S. and Asian demand was weak, especially during the latter half of the year, whereas European demand was reported to be steady.

Unwrought aluminum inventories held by members of the IAI decreased slightly to 1.79 Mt at yearend 2000 from 1.80 Mt at yearend 1999. Unwrought aluminum is defined by the IAI as aluminum in its basic cast form made from primary metal or from scrap and which is unworked in the metallurgical sense. IAI total aluminum inventories decreased to 3.09 Mt at yearend 2000 from 3.18 Mt at yearend 1999. Total aluminum is unwrought aluminum plus unprocessed scrap, metal in process, and finished semifabricated (mill) products (International Aluminium Institute, 2001).

Inventories of primary aluminum metal held by the LME decreased dramatically from 774,000 t at yearend 1999 to 322,000 t at yearend 2000. Aluminum alloy inventories, however, increased to 88,000 t at yearend 2000 from 78,000 t at yearend 1999 (London Metal Exchange Ltd., 2000).

Armenia.—The Government of Armenia and Russia's Sibirsky Aluminy signed a joint-venture agreement to rebuild the Armenal foil mill in Yerevan. Sibirsky agreed to invest about $32 million in exchange for 44% of the plant ownership. The remaining 56% would remain with the state-controlled Kanaker Aluminum Works. The mill, which had been idled for 6 years, was expected to reach its full capacity of about 2,200 t/mo of foil by the middle of 2001. Sibirsky planned to increase its ownership to 74% over 3 or 4 years (Interfax Mining & Metals Report, 2000a).

Australia.—Capral Aluminium Ltd. sold its 150,000 t/yr Kurri Kurri primary aluminum smelter in New South Wales to Germany's VAW Aluminium AG (Platt's Metals Week, 2000g). VAW, whose worldwide smelter capacity increased by 30% to 575,000 t/yr with this purchase, announced plans to modernize and expand capacity at Kurri Kurri by 15,000 t/yr before 2003 (Metal Bulletin, 2000w). Capral also announced plans to phase out its sheet rolling operations at Granville by the end of 2000. The associated metal recycling and remelt facility would be retained and converted to extrusion billet production. Capral intended to concentrate on its downstream processing and distribution business (Metal Bulletin, 2000g).

Rio Tinto plc became the sole owner of Comalco Ltd., a major Australian supplier of bauxite, alumina, and primary aluminum metal to the world market. Rio Tinto acquired the publicly held 27.6% of Comalco during the first half of 2000. Comalco's interests include the Weipa bauxite mine (100%) in Queensland, the Boké Mine (4%) in Guinea, the Gladstone alumina refinery (30%) in Queensland, the Eurallumina refinery (56%) in Italy, the Bell Bay (100%) and Boyne Island (54%) smelters in Australia, and the Tiwai Point smelter (79%) in New Zealand (Rio Tinto plc, 2001, p. 39).

Pechiney agreed to purchase AMP Life Limited's 15.5% direct stake in the Tomago primary aluminum smelter in New South Wales. The purchase would increase Pechiney's interest in the 440,000 t/yr smelter to 51.55% from 36.05%. The other participants in the Tomago joint venture are Gove Aluminium Finance Ltd. (36.05%) and VAW Tomago Inc. and VAW Australia Pty Ltd. with a combined stake of 12.4% (Pechiney, 2000a).

Alcoa of Australia Limited, a joint venture of Alcoa Inc. and WMC Ltd., announced the restart of its idled capacity at the Portland and Point Henry primary aluminum smelters. The capacity had been idled since the mid-1990s. Alcoa of Australia was operator and part owner of the 450,000-t/yr Portland smelter and 100% owner/operator of the 180,000-t/yr Point Henry smelter (American Metal Market, 2000b). On September 15, Alcoa increased its ownership in the Portland smelter to 55% from 45% with the purchase of Eastern Aluminium Ltd. (Alcoa, 2001b, p. 10-11).

Azerbaijan.—Fondel Metal Participants, a Dutch company, won a tender for the management of Azerbaijan's aluminum holding company, Azeraluminy. Fondel agreed to modernize the company's facilities that include the 60,000-t/yr Sumgait smelter, the Gyandja alumina refinery, and local alunite mines. The Gyandja refinery, which can process both imported bauxites and local alunite ore, was the company's only operational facility in 2000 (Metal Bulletin, 2000d).

Bahrain.—The Government of Bahrain approved in principle a $1.7 billion expansion project for Aluminium Bahrain B.S.C. (Alba) and passed the proposal on to the ministerial committee of finance and economy for further study. The project, if approved, would increase capacity at Alba's 500,000-t/yr primary aluminum smelter to 750,000 t/yr (American Metal Market, 2000a).

Brazil.—Vale do Rio Doce Alumínio S.A. (Aluvale) reported the start of a 43,000-t/yr expansion at its Alumínio Brasileiro S.A. (Albrás) primary aluminum smelter. The $90 million expansion at the 361,000-t/yr smelter was expected to be completed by September 2001 (Metal Bulletin, 2000a).

Cia Brasileira de Alumínio (CBA) began construction on a 70,000-t/yr expansion at its 237,000-t/yr primary aluminum smelter in Sao Paulo. The $400 million project, which also included investments in CBA's hydroelectric plants, was expected to be completed by the end of 2002 (Kinch, 2000).

Billiton plc acquired an indirect 2.1% stake in Companhia Vale do Rio Doce (CVRD) through its purchase of a 66.97% share of Sweet River Investment Ltd. The Sweet River assets correspond to a 7.74% share of Valepar SA, the controlling shareholder of CVRD. CVRD through its fully owned subsidiary Aluvale, has interests in the Albras and Santa Cruz primary aluminum smelters (Billiton plc, 2000a).

Canada.—On October 21, approximately 32 months after groundbreaking ceremonies, the first reduction cell at Alcan Aluminium Ltd.'s Alma smelter was energized. Startup of the smelter's 432 reduction cells will continue through the fall of

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2001, at which time the smelter was expected to reach its full capacity of 400,000 t/yr (Alcan Aluminium Ltd., 2000i).

On December 8, Alcan announced that it would temporarily close 50,000 t/yr of capacity at its primary aluminum smelter in Kitimat, British Columbia, for at least 10 months. Alcan believed that the temporary shut down and other energy reduction steps would conserve enough energy to keep the other six potlines at the 272,000-t/yr smelter operational. An acute shortage of water in the Nechako Reservoir, the result of 3 consecutive years of low inflows into the reservoir, reduced the hydroelectric power availability and forced the company to take this action (Alcan Aluminium Ltd., 2000j).

Workers at the 372,000-t/yr Aluminerie de Bécancour primary smelter in Quebec accepted a new 4-year labor agreement that reportedly included a 3% wage increase the first year and 2.8% increases each year thereafter. The previous 6-year contract expired on June 30 (Platt's Metals Week, 2000a).

Lavalum, a joint venture of scrap processor SNF/Quebec Metal Recycle Inc. and the provincial Government of Quebec, announced the opening a new secondary aluminum smelter. The smelter was expected to produce 2,950 t/mo (6.5 million pounds per month) of aluminum alloys (Worden, 2000b).

China.—During the year, numerous expansion plans for primary aluminum smelters throughout China were announced.

Baotou Aluminium Group planned to add a new 50,000-t/yr potline to its 110,000-t/yr smelter by the end of 2001 (Platt's Metals Week, 2000e).

The 20,000-t/yr Hubei Aluminium Smelter received Government approval to proceed with a planned 100,000-t/yr expansion program (CRU Aluminium Monitor, 2000a).

Work reportedly began on the 100,000-t/yr expansion at the 85,000-t/yr Lanzhou Aluminium Smelter. Completion of the project was expected in 2 to 3 years (American Metal Market, 2000e).

The Taiiyuan Aluminium Works in Shanxi Province began construction work on a planned 80,000-t/yr expansion at its 30,000-t/yr primary aluminum smelter. Once the new line became operational at the end of 2001, the company planned to close one of the two existing 15,000-t/yr potlines because of pollution factors (Platt's Metals Week, 2000q).

Tongchuan Aluminium Industry commissioned a new 5,000-t/yr potline at its 50,000-t/yr smelter in Shaanxi Province (CRU Aluminium Monitor, 2000b).

Xiezhou Aluminium Plant in Shanxi Province reported the completion of a new 40,000-t/yr potline at its 30,000-t/yr smelter. The company planned to upgrade the existing potlines and increase capacity to 100,000 t/yr by the end of 2001 (Platt's Metals Week, 2000t).

Yunnan Aluminium Plant reportedly completed its smelter expansion increasing capacity from the previous 40,000 t/yr to 130,000 t/yr. The company was awaiting Government approval to further expand the smelter's capacity to 250,000 t/yr (Platt's Metals Week, 2000u).

Zunyi Aluminium Plant started construction on a new 100,000-t/yr potline at its 32,000-t/yr smelter in Guizhou Province, which could be completed in 2002 (Platt's Metals Week, 2000v).

Egypt.—The Aluminium Company of Egypt (Egyptalum) announced plans to increase capacity at its 195,000-t/yr primary smelter to 245,000 t/yr by 2002. In October 1997, a 50,000-t/yr prebaked potline was commissioned and an existing potline (Potline 5) was shut down. Egyptalum expects to complete the conversion of Potline 5 to prebake technology by mid-2002, thereby increasing the smelter's capacity to 245,000 t/yr (Aluminium Company of Egypt, Smelter, accessed May 25, 2001, at URL http://www.egyptalum.com.eg/smelter.html).

France.—PSA Peugot Citroën and Pechiney signed a strategic partnership agreement for the development of aluminum applications in Peuleot and Citroën vehicles. The 10-year agreement provides the framework for cooperation between the two groups with the aim of increasing production of mass-produced aluminum parts and making innovative developments for vehicle weight reduction (Pechiney, 2000b).

Germany.—VAW Aluminium AG and Sweden's Sapa AB, formerly Gränges AB, terminated their agreement aimed at VAW taking over Sapa's foil business, Eurofoil. VAW reported that it had withdrawn its application with the German cartel office after it became apparent that the office would not give its approval. The former agreement had included foil mills in Belgium, Luxembourg, and Sweden (Köhl, 2000).

Hungary.—Magyar Aluminium Rt (MAL) integrated its affiliates into one holding company to reduce administrative overhead and to simplify strategic planning. MAL incorporated Ajkai Timfold, owner of the 300,000-t/yr Ajka alumina refinery, and Inotai Aluminium, which owns 93% of the 35,000-t/yr Inota aluminum smelter (Metal Bulletin, 2000m).

India.—Alcan announced the sale of its 54.62% interest in Indian Aluminium Co., Ltd. (Indal) to Hindalco Industries Ltd. The purchase included about 100,000 t/yr of primary aluminum smelter capacity (Metal Bulletin, 2000b).

Hindalco's board of directors approved a $575 million expansion of its operations in Renukoot. Aluminum smelter capacity would be expanded to 342,000 t/yr from 242,000 t/yr and the alumina refinery capacity would increase to 660,000 t/yr from 450,000 t/yr. The expansion was expected to be completed by July 2002 (Raghuvanshi, 2000).

Expansion plans continued at National Aluminium Co. Ltd. Bauxite production capacity at the Panchpatmali Mine was scheduled to double to 4.8 Mt/yr by 2001. Capacity at the 800,000-t/yr alumina refinery at Damanjodi was expected to increase to 1.575 Mt/yr in early 2002, and the Angul smelter expansion that would increase capacity to 345,000 t/yr from 230,000 t/yr was expected to be commissioned by mid-2002 (Hall, 2000).

Indonesia.—Production at P.T. Indonesia Asahan Aluminium Co.'s (PT Inalum) primary aluminum smelter returned to 85% to 90% of its 225,000-t/yr capacity with 440 of its 510 pots on-line. Receding water levels in Lake Toba in 1998-99 had reduced hydroelectric power generation forcing PT Inalum to reduce production levels at the smelter by as much as 60% in mid-1998 (Platt's Metals Week, 2000c).

Iran.—The production rate at Almahdi Aluminium Corp.'s primary aluminum smelter at Bandar Abbas reached about 25,000 t/yr. The company expected the smelter, which was commissioned in June 1997, to reach full production of 110,000 t/yr by the end of 2001 (Metal Bulletin, 2000e).

Japan.—Alcoa announced that construction had begun on a new forged aluminum commercial vehicle wheel plant in Joetsu City, Niigata Prefecture, to meet increased demand for polished aluminum truck and bus wheels in Japan. The plant was expected to be operational by the latter half of 2001 and to reach full capacity in late 2002 (Alcoa Inc., 2000d).

Nippon Light Metal Co. Ltd. announced a major restructuring of its extrusion business that would close one-third of the

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company's 33 extrusion lines by the end of March 2001. The company also reported the curtailment of production of aluminum substrates for computer disks (Metal Bulletin, 2000p).

Mitsubishi Materials Corp. and Mitsubishi Aluminium Co. Ltd. announced plans to build an integrated aluminum recycling plant that would consolidate aluminum UBC recycling operations that were being conducted at several different locations. The plant would convert UBCs into slabs ready for rolling into can stock. Slab production, which was expected to start in 2001, was estimated at 60,000 t/yr (Metal Bulletin, 2000o).

Korea, Republic of.—Alcan, through its subsidiary Alcan Taihan Aluminium Limited, acquired Aluminium of Korea Limited (Koralu). The acquisition of Koralu positioned Alcan as Asia's leading aluminum rolled products company. The Koralu facility included casting, hot rolling, cold rolling, and extensive finishing operations as well as aluminum foundry alloy and billet operations supported by a research and development center (Alcan Aluminium Ltd., 2000e).

Malaysia.—Malaysia's Aluminium Industries commissioned a new aluminum foil mill. The plant was capable of producing foil down to 0.006 millimeters thickness for the pharmaceutical and food packaging industries (Metal Bulletin, 2000n).

Mexico.—Hayes Lemmerz launched a capacity expansion program at its Chihuahua wheel plant that was expected to increase production to 1.2 million cast light-alloy wheels per year from 300,000 wheels per year (Wrigley, 2000e).

Mozambique.—On September 29, the Mozambique Aluminium Co.'s (Mozal) primary aluminum smelter near Maputo was officially opened. The feasibility study for the smelter started in November 1995, and construction began in May 1998. The 250,000-t/yr smelter uses Pechiney's AP30S technology and has one potline with a total of 288 pots. The smelter is a joint venture involving Billiton plc (47%), Mitsubishi Corp. (25%), the Industrial Development Corp. of South Africa Ltd. (24%), and the Government of Mozambique (4%). The smelter produced its first metal on June 18, 2000, and exported its first consignment of ingots to Europe in August (Billiton plc, 2000b; Millbank, 2000). By the end of December, all 288 pots were in operation (Mozambique Aluminium Co., 2000). Billiton reported that the company will complete feasibility studies into the possible construction of a second 250,000-t/yr potline at Mozal. Any decision, however, could be at least a year away (Metal Bulletin, 2000l).

Nigeria.—Reynolds, which was merged with Alcoa, transferred its 10% interest in Aluminium Co. of Nigeria (Alscon) to the other private partner in the company, Germany's Ferrostaal AG, whose ownership increased to 30%. The remaining 70% of Alscon was owned by the Nigerian government. The responsibility for the technical running of the 193,000-t/yr smelter, which has been closed since June 1999, was also transferred from Reynolds to Ferrostaal (Metal Bulletin, 2000r).

Norway.—Elkem ASA's aluminum operations are organized in Elkem Aluminium ANS, a 50-50 partnership with Alcoa. In 2000, Alcoa acquired over 30% of the outstanding shares of Elkem ASA (Alcoa Inc., 2001b, p. 10).

Elkem Aluminium ANS announced plans to modernize and expand its 121,000-t/yr Mosjøen primary aluminum smelter. Two of the plants four potrooms (two potlines) were converted from Soderberg to prebaked technology in 1989. The remaining Soderberg line is scheduled to be converted and expanded by 2003. Upon completion, annual capacity at the smelter would increase to 188,000 t/yr (Elkem ASA, 2000).

Meanwhile, conversion work on Potrooms 1 and 2 at the 83,000-t/yr Lista smelter was expected to be completed in the first half of 2001. The installation of a new Soderberg technology was expected to yield significant environmental improvements while increasing production capacity by 10,000 t/yr (Elkem ASA, 2001, p. 26).

Norsk Hydro ASA confirmed that the company will invest approximately $600 million in the expansion and modernization of its Sunndal primary aluminum smelter. A new smelter with a production capacity of 238,800 t/yr will be built on the site and a 66,000-t/yr Soderberg facility, which was started in 1954, will be closed gradually to prevent the loss of production during construction. The company stated that the remaining 90,000 t/yr of existing capacity will continue to operate. The new smelter will consist of 340 new cells using Hydro's HAL250 technology. Upon completion in 2004, total capacity at the site will increase to 328,800 t/yr, making it the largest aluminum smelter in Europe (outside of Russia). The design of the cell linings and rectifiers will be such that amperage can gradually be increased, providing an additional 22,000 t/yr of production capacity by 2007 (Norsk Hydro ASA, 2000a: Norsk Hydro ASA, 2001b).

Oman.—A feasibility study for a proposed $2.5 billion, 480,000-t/yr primary aluminum smelter in Sohar was completed. An implementation review to identify potential technologies and project funding was begun (Mining Journal, 2000b).

Russia.— A new aluminum company, Russky Aluminy (Russian Aluminium), was formed by combining the assets of the Sibneft shareholder group and Siberian Aluminium. Russian Aluminium manages about 70% of Russia's primary aluminum smelting capacity. The company controls Russia's three largest smelters—Bratsk (900,000 t/yr), Krasnoyarsk (800,000 t/yr), and Sayansk (400,000 t/yr). On the alumina side, the company controls the Achinsk (900,000 t/yr) and the Nikolayev (1.05 Mt/yr) refineries. The downstream operations that are either fully or partly owned by the company include the Samara Metallurgical Plant, the Sayanal foil mill, the Rostar can plant, and the Belaya Kalitva Metallurgical Production Assn. (Metal Bulletin, 2000s).

A second new group, SUAL Holding, was a merger of the aluminum assets of Siberian-Urals Aluminium Co. and the Trustconsult Group. SUAL controls the Irkutsk (262,000 t/yr), Bogoslovsk (162,000 t/yr), Uralsky (70,000 t/yr), and Kandalaksa (63,000 t/yr) primary aluminum smelters. The company also owns the Bogoslovsk (930,000 t/yr) and Uralsky (570,000 t/yr) refineries, the Northern and Southern Urals bauxite mines plus the Srende-Timan bauxite deposits (CRU Alumina Monitor, 2000). Downstream facilities include the Kamensk-Uralsky Metallurgy Plant (rolling mill), the Mikhailovsky Nonferrous Metal Processing Plant (Mikhalum foil plant), and the Irkutsk and Kirinsky cable plants (Interfax Mining & Metal Report, 2000d).

Scotland.—Alcan reported the closure of its 8,000-t/yr primary aluminum smelter in Kinlochleven. The Kinlochleven smelter, built in 1907, was one of the world's oldest smelters still in operation (Alcan Aluminium Ltd., 2000f).

South Africa.—Billiton was conducting a feasibility study for an additional 125,000-t/yr potline at its 500,000-t/yr Hillside

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smelter (Mining Journal, 2000a).

Spain.—Alcoa Inespal built a new aluminum extrusion plant at La Salva del Camp to make extruded aluminum profiles for the automotive and construction industries. By yearend, a 1,350-t press with an output of 4,000 t/yr was operational. A second line was expected to startup in August 2001, doubling the plant's capacity (Alcoa Inc., 2001a, p. 24).

Norsk Hydro announced plans to build a 60,000-t/yr aluminum remelt plant in Azuqueca near Madrid. The plant, which will produce extrusion ingot from scrap for growing markets in Spain and Portugal, was expected to be completed by yearend 2001 (Norsk Hydro ASA, 2000e).

Sweden.—Gränges AB changed its name to Sapa AB. Sapa was already being used as a corporate and brand name by Gränges' aluminum extrusion division. The formal change of name and company logo took place in mid-February (Metal Bulletin, 2000k).

Glencore International AG reported that it had acquired Kubikenborg Aluminium Sundsvall AB (KAS), owner of the 100,000-t/yr primary aluminum smelter in Sundsvall, Sweden. KAS had been formed by the plant's management group that bought the smelter from Gränges in 1998 (American Metal Market, 2000d).

Switzerland.—Algroup, the aluminum division of Alusuisse Lonza Group Inc., announced its decision to continue the operation of its 35,000-t/yr primary aluminum smelter at Steg at least until the end of 2005. The continuation of the Steg plant, which was originally scheduled for closure at the end of 2001, became possible because of the extension of a fixed power price and supply contract to 2005. The continuation of plant operations will require some technical adjustments that will result in an increase in capacity to 43,000 t/yr (algroup, 2000).

Norsk Hydro signed an agreement with Aluminium Martigny S.A. to continue operating its remelt plant in Martigny. The agreement saved the plant, which produced about 25,000 t/yr of extrusion billet and foundry alloys, from imminent closure. While the potrooms at the Martigny primary smelter will remain closed, Norsk Hydro will operate the casthouse to produce specialty products for extruders and foundries in Europe (Norsk Hydro ASA, 2000d).

Taiwan.—New Sun Metal Industry Co. completed the expansion of its secondary aluminum smelter that increased capacity to 156,000 t/yr. The expansion enabled the company to diversify into sheet rolling, t-bar, anode, and deox production (Metal Bulletin, 2000u).

United Kingdom.—Alcan reported the restart of 50,000 t/yr of primary aluminum capacity at its smelter in Lynemouth to compensate for the closure of Alcan's Isle Maligne smelter in Canada and the Kinlochleven smelter in Scotland. The restart was completed by the end of the year (Alcan Aluminium Ltd., 2000f).

Alcan also announced the planned closure of its foil plant in Rogerstone, Newport, South Wales by June 2001. Some products will be transferred to other plants in the Alcan network but the majority of the plant's business will be discontinued. The larger Rogerstone sheet facility on the same site will continue to operate and remain a key part of Alcan's sheet manufacturing system in Europe (Alcan Aluminium Ltd., 2000d).

Alcoa announced the acquisition of British Aluminium. The acquisition included three soft-alloy extrusion operations at Banbury, St. Helens, and Latchford, England; a heat-treat plate mill in Kitts Green, Birmingham, England; and a sheet mill in Dolgarrog, Wales. The acquisition also included two distribution businesses, Baco Metal Centres and Aluminium Supply Aerospace, with branches located throughout the United Kingdom and Ireland (Alcoa Inc., 2000l).

Alcoa also acquired Baco Consumer Products, Ltd., headquartered near London. Baco is the United Kingdom's leading supplier of household wraps, including aluminium foil, plastic bags, cling film, and trash bags (Alcoa Inc., 2000c).

Alcoa announced the acquisition of MCG Closures Limited from Wassall plc. The acquisition included plants near Birmingham, England; Rieti, Italy; and a distribution center in the Netherlands. MCG became part of Alcoa Closure Systems International, 1 of 25 Alcoa business units and a leading global manufacturer of plastic closures for the beverage industry (Alcoa Inc., 2000a).

Norsk Hydro signed an agreement with Aluminium Holding UK Ltd. to purchase its entire shareholding in Deeside Aluminium Ltd. in Wrexham, Wales. Deeside operates an extrusion ingot casting plant that uses aluminum scrap as a feed source. The plant has an output of 38,000 t/yr of extrusion ingot. Upon approval of the takeover by the United Kingdom authorities, Norsk Hydro plans a significant improvement program that will improve productivity and increase capacity to 43,000 t/yr. The improvement program will also pave the way for a possible future expansion to 60,000 t/yr (Norsk Hydro ASA, 2000c).

Ukraine.—Kaiser completed a technical feasibility study for the reconstruction of smelting capacity at Zaporozhye Aluminum Works (Zalk). The conversion of the smelter's Soderberg technology to prebaked anode technology was expected to increase capacity at the 110,000-t/yr primary aluminum smelter to about 160,000 t/yr and to reduce costs. Financing for this conversion was expected to be secured from the sale of 68.1% of the state-owned shares in the company. The Government would retain 25% of the shares and employees 6.9% (Interfax Mining & Metals Report, 2000c). At the end of November, the Ukranian State Property Fund announced that Kremenchug Auto Works (Kraz) Foreign Trade Company had won the tender for the shares in Zalk with a bid of $101.5 million. Glencore International reportedly owns about 90% of the shares in Kraz Foreign Trade Company (Interfax Mining & Metals Report, 2000b).

Ukrainian Aluminium Co., a company linked with Russia's Sibirsky Aluminy, purchased a 30% stake in the 1.05 Mt/yr Nikolayev alumina plant. Ukrainian Aluminium planned to modernize the alumina plant and increase its capacity to 1.3 Mt/yr. As a condition of the sale, the company also agreed to build a primary aluminum smelter in the Ukraine (Platt's Metals Week, 2000n). Construction of the new 100,000-t/yr smelter was due to begin by 2002 and would take 5 to 6 years to complete (Platt's Metals Week, 2000s). By the end of 2000, Ukrainian Aluminium acquired an additional 15% stake in the Nikolayev alumina refinery (Platt's Metals Week, 2000r).

Venezuela.—Norsk Hydro acquired a 33.3% stake in Pianmeca, located in Puerto Ordaz next to the Venalum smelter, which will supply liquid aluminum to the casthouse. Pianmeca expected to produce 30,000 t of extrusion ingots and 8,000 t of wire rod in 2001. Norsk Hydro planned to increase future production levels at the plant through investments and plant improvements (Norsk Hydro ASA, 2000f).

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Technology

Toronto University scientists completed an evaluation of Aluminum Power Inc.'s aluminum-air fuel cell. The scientists reported that "although nickel-metal-hydride and lithium-ion battery systems represent a tremendous advance in battery technology, their power pales in comparison with the energy available from an aluminum-air cell." The cell generates power through an electro mechanical reaction between the aluminum, placed in an alkaline solution, and oxygen from the air. Electricity is produced as the aluminum oxidizes in the alkaline solution. Key to the cell's effectiveness is its high energy output, which results from the characteristic energy density of aluminum and the fact that three electrons are released for every atom of aluminum reacted (American Metal Market, 2000g).

The aluminum-air cell technology can be adapted to a variety of applications, including electric vehicles, emergency power sources, and portable electronic devices. Aluminum Power announced that it had achieved 8 hours of talk time and 5½ days of standby power using its newly developed aluminum-air fuel cell for mobile telephones in a digital mode compared with 2 hours of talk time for lithium-ion or nickel-cadmium batteries. The company claimed that when the technology is perfected about 25 hours of talk time and 240 hours of standby power would be possible (Pinkham, 2000).

Outlook

Weakness in the national economies of most areas of the world is expected to lead to very little growth, or possibly a small decrease, in demand for aluminum in 2001. It is anticipated that this weakness will be short-lived and that demand will pick up in 2002 and thereafter.

On the supply side, energy costs and shortages continued to force companies to temporarily idle smelter capacity. By July 2001, the United States had idled almost 1.8 Mt of capacity; combined with announced capacity reductions in Brazil and Canada, almost 2.2 Mt/yr of production capacity was removed from the world supply. However, the reduction in demand and additional production, from new smelters in Canada and Mozambique plus brownfield expansions that are coming on-stream, are expected to keep world supply and demand fairly balanced in 2001. In later years, however, if demand picks up and the energy cost and supply situations have not been reversed, shortages could appear.

On the demand side, the automotive and construction industries are expected to be the drivers for aluminum demand in the future. Growth in the packaging and container industry has stabilized, especially in the United States and Europe. There is still room for growth in the packaging industries of Asia and Latin America, but even there the growth rate over the past few years has slowed. Overall, world demand is expected to continue to grow, despite a possible drop in the growth rate for the next year or so as the world economies begin their recoveries.

References Cited

Alcan Aluminium Ltd., 2000a, Alcan and algroup to merge: Montreal and Zurich, Alcan Aluminium Ltd. press release, June 1, 2 p.

———2000b, Alcan and Ford sign multi-year supply agreement for automotive aluminum: Montreal, Alcan Aluminium Ltd. press release, January 24, 3 p.

———2000c, Alcan announces expansion project to increase billet production at Sebree: Henderson, KY, Alcan Aluminium Ltd. press release, August 9, 2 p.

———2000d, Alcan announces the planned closure of Rogerstone Foil operations: Uxbridge, UK, Alcan Aluminium Ltd. press release, April 12, 1 p.

———2000e, Alcan finalized the acquisition of Koralu: Montreal, Alcan Aluminium Ltd. press release, May 9, 1 p.

———2000f, Alcan restarts potlines at its Sebree and Lynemouth smelters: Montreal, Alcan Aluminium Ltd. press release, May 10, 1 p.

———2000g, Alcan to expand light gauge capacity with investment at Indiana rolling mill: Terre Haute, IN, Alcan Aluminium Ltd. press release, August 14, 1 p.

———2000h, Merger a success, launch of the new Alcan: Montreal and Zurich, Alcan Aluminium Ltd. press release, October 18, 2 p.

———2000i, Successful start-up of first reduction cell–Alma smelter produces first metal: Montreal, Alcan Aluminium Ltd. press release, October 30, 1 p.

———2000j, Unprecedented water shortage forces Alcan to curtail production in B.C.: Montreal, Alcan Aluminium Ltd. press release, December 8, 1 p.

Alcoa Inc., 2000a, Alcoa acquires MCG Closures Limited: London, Alcoa Inc. press release, April 7, 1 p.

———2000b, Alcoa acquires primary grade aluminum particle ingot producer C-KOE Aluminum: Pittsburgh, Alcoa Inc. press release, August 29, 1 p.

———2000c, Alcoa acquires U.K.-based Baco Consumer Products, Ltd.: Pittsburgh, Alcoa Inc. press release, August 4, 1 p.

———2000d, Alcoa announces plan to build wheel plant: Pittsburgh, Alcoa Inc. press release, October 24, 1 p.

———2000e, Alcoa completes acquisition of Cordant: Pittsburgh, Alcoa Inc. press release, May 25, 1 p.

———2000f, Alcoa completes acquisition of Howmet: Pittsburgh, Alcoa Inc. press release, June 20, 1 p.

———2000g, Alcoa completes merger with Reynolds Metals: Pittsburgh and Richmond, Alcoa Inc. press release, May 3, 1 p.

———2000h, Alcoa purchases Noranda Aluminum Inc.'s Excel Extrusions unit: Pittsburgh, Alcoa Inc. press release, January 7, 1 p.

———2000i, Alcoa to build cast aluminum rod facility: Cressona, PA, Alcoa Inc. press release, November 29, 1 p.

———2000j, Alcoa to curtail production at Troutdale aluminum smelter: Pittsburgh, Alcoa Inc. press release, June 28, 1 p.

———2000k, Alcoa to restart primary aluminum production: Pittsburgh, Alcoa Inc. press release, January 19, 1 p.

———2000l, European Commission approves Alcoa's acquisition of British Aluminium businesses: Pittsburgh, Alcoa Inc. press release, October 27, 1 p.

———2000m, Michigan Avenue Partners to acquire Alcoa's Longview aluminum smelter: Pittsburgh and Chicago, Alcoa Inc. press release, December 27, 1 p.

———2001a, Annual report—2000: Pittsburgh, Alcoa Inc., 68 p.

———2001b, Form 10-K—2000: Securities and Exchange Commission, 46 p.

algroup, 2000, algroup will continue the operation of its aluminium smelter at Steg (Switzerland) until the end of 2005 and expand capacity: Zurich, algroup press release, May 26, 2 p.

Aluminum Association Inc., 2001a, Americans recycle 2 of 3 aluminum cans: Washington, DC, Aluminum Association Inc. press release, April 19, 4 p.

———2001b, The aluminum situation: Aluminum Association Inc., February, 4 p.

American Metal Market, 2000a, Alba capacity hike advances: American Metal Market, v. 108, no. 220, November 14, p. 10.

———2000b, Alcoa plans Australian restart: American Metal Market, v. 108, no. 83, May 1, p. 2.

———2000c, Ball to close beverage can line: American Metal Market, v. 108, no. 117, June 19, p. 2.

———2000d, Glencore seals KAS acquisition: American Metal Market, v. 108, no. 205, October 24, p. 8.

———2000e, Lanzhou smelter lifts capacity: American Metal Market, v. 108, no. 174, August 8, p. 2.

———2000f, Quanex completes Temroc acquisition: American Metal Market, v. 108, no. 232, December 4, p. 8.

———2000g, Scientists outline advantages of aluminum-air cell battery: American Metal Market, v. 108, no. 133, July 12, p. 4.

Billiton plc, 2000a, Billiton to acquire a minority interest in Valepar SA: London, Billiton plc press release, July 26, 2 p.

———2000b, Mozal smelter officially opened: London, Billiton plc press release, September 29, 1 p.

Butler Manufacturing Co., 2000, Butler to build $24 million Vistawall plant in Tennessee: Kansas City, MO, Butler Manufacturing Co. press release, April 4, 1 p.

Commonwealth Industries Inc., 2000, Commonwealth Aluminum signs long-term supply agreement: Louisville, KY, Commonwealth Industries Inc. press release, October 4, 2 p.

CRU Alumina Monitor, 2000, Industry News: CRU Alumina Monitor, October,

Digitized by Google

p. 6.
CRU Aluminium Monitor, 2000a, Industry News: CRU Aluminium Monitor, January, p. 11.
———2000b, Industry News: CRU Aluminium Monitor, August, p. 11.
Elkem ASA, 2000, Modernization and expansion of Elkem Aluminium Mosjøen: Oslo, Norway, Elkem ASA press release, December 20, 1 p.
———2001, Annual report—2000: Oslo, Norway, Elkem ASA, 78 p.
Hall, Andrew, 2000, The aluminum industry in India: Light Metal Age, v. 58, no. 9, 10, October, p. 48-52.
IMCO Recycling Inc., 2000, IMCO Recycling says second quarter net will be well below estimate, expects better second half: Irving, TX, IMCO Recycling Inc. press release, June 20, 2 p.
———2001a, Annual report—2000: Irving, TX, IMCO Recycling Inc., 37 p.
———2001b, IMCO Recycling shuts down processing capacity in Indiana and expects fourth quarter loss: Irving, TX, IMCO Recycling Inc. press release, January 22, 2 p.
Indalex Aluminum Solutions Group, 2000a, Indalex launches $42 (US) million expansion of three plants in North America: Bannockburn, IL, Indalex Aluminum Solutions Group press release, November 10, 2 p.
———2000b, 2nd largest North American extruder restructures business and invests in new Toronto plant: Toronto, Indalex Aluminum Solutions Group press release, April 27, 1 p.
Interfax Mining & Metals Report, 2000a, Armenal JV to produce 550 tonnes of foil in July: Interfax Mining & Metals Report, v. 9, issue 28, July 7-13, p. 10.
———2000b, Glencore International subsidiary wins Zaporozhye Aluminum tender: Interfax Mining & Metals Report, v. 9, issue 49, December 1-7, p. 5.
———2000c, Kaiser Aluminum completes Zaporozhye plant feasibility study: Interfax Mining & Metals Report, v. 9, issue 33, August 11-17, p. 10.
———2000d, Russia's second largest aluminum holding company set up: Interfax Mining & Metals Report, v. 9, issue 38, September 15-21, p. 3-4.
International Aluminium Institute, 2001, Aluminium inventories: International Aluminium Institute Form 351, February 12, 2 p.
Kaiser Aluminum & Chemical Corp., 2000a, Kaiser Aluminum says new labor contract enables sweeping productivity improvement; company to record one-time charge for settlement costs: Houston, TX, Kaiser Aluminum & Chemical Corp. press release, September 18, 3 p.
———2000b, Kaiser Aluminum to curtail additional Northwest smelter capacity; power sale proceeds to help mitigate employee impact: Houston, TX, Kaiser Aluminum & Chemical Corp. press release, November 20, 2 p.
Kinch, Diana, 2000, Brazilians resume smelter expansions: Metal Bulletin Monthly, no. 351, March, p. 18-21.
Köhl, Christian, 2000, Sapa, VAW end Eurofoil deal: American Metal Market, v. 108, no. 109, June 7, p. 16.
London Metal Exchange Ltd., 2000, Aluminium stocks: London Metal Exchange Ltd., December 29, 2 p.
Metal Bulletin, 2000a, Albrás primary aluminium expansion on schedule: Metal Bulletin, no. 8506, September 7, p. 9.
———2000b, Alcan withdraws from India to focus on flat-rolled opportunities: Metal Bulletin, no. 8462, March 27, p. 9.
———2000c, Alcoa buys Micromill from Kaiser: Metal Bulletin, no. 8447, February 3, p. 4.
———2000d, Al production may restart at Sumgait: Metal Bulletin, no. 8525, November 13, p. 5.
———2000e, Bandar Abbas smelter raises production: Metal Bulletin, no. 8486, June 22, p. 8.
———2000f, Behr increases secondary aluminium capacity: Metal Bulletin, no. 8455, March 2, p. 9.
———2000g, Capral to close its rolling business: Metal Bulletin, no. 8474, May 11, p. 4.
———2000h, Century in labour agreement at Hawesville: Metal Bulletin, no. 8514, October 5, p. 5.
———2000i, Columbia Falls cuts 51,000 tpy of production as power costs bite: Metal Bulletin, no. 8533, December 11, p. 5.
———2000j, Golden Northwest Aluminium cuts more production: Metal Bulletin, no. 8537, December 29, p. 3.
———2000k, Gränges takes Sapa name: Metal Bulletin, no. 8446, January 31, p. 15.
———2000l, Here comes Mozal II: Metal Bulletin, no. 8511, September 25, p. 14.
———2000m, Hungarian producer forms new holding company: Metal Bulletin, no. 8497, July 31, p. 3.
———2000n, Malaysian firm installs new aluminium foil mill: Metal Bulletin, no. 8533, December 11, p. 7.
———2000o, New Al can recycling plant planned for Japan: Metal Bulletin, no. 8498, August 7, p. 10.
———2000p, NLM plans major restructuring programme: Metal Bulletin, no. 8458, March 13, p. 5.
———2000q, Pechiney sells remaining ANC stake: Metal Bulletin, no. 8465, April 6, p. 4.
———2000r, Reynolds pulls out of Alscon: Metal Bulletin, no. 8532, December 7, p. 4.
———2000s, Russky Aluminy works on consolidating assets, building market share and developing alumina: Metal Bulletin, no. 8495, July 24, p. 6.
———2000t, Scottsboro Aluminum and USW agree deal: Metal Bulletin, no. 8461, March 23, p. 4.
———2000u, Taiwan's secondary aluminium smelter completes expansion plan: Metal Bulletin, no. 8527, November 20, p. 21.
———2000v, Vanalco shuts down last potline: Metal Bulletin, no. 8510, September 21, p. 5.
———2000w, VAW wants to buy Capral's Kurri Kurri smelter: Metal Bulletin, no. 8484, June 15, p. 5.
Millbank, Paul, 2000, Mozambique moves onto the metals map: Metal Bulletin Monthly, no. 357, September, p. 36-41.
Mining Journal, 2000a, Billiton looks to expand: Mining Journal, v. 334, no. 8572, March 3, p. 183-185.
———2000b, Sohar smelter study complete: Mining Journal, v. 334, no. 8566, January 21, p. 40-41.
Mozambique Aluminium Co., 2000, 288 pots in operation: Maputo, Mozambique, Mozal press release, November-December, 1 p.
Norsk Hydro ASA, 2000a, Europe's largest aluminium plant: Oslo, Norway, Norsk Hydro ASA press release, August 16, 2 p.
———2000b, Extrusion completes Wells deal: Oslo, Norway, Norsk Hydo ASA press release, February 24, 1 p.
———2000c, Hydro to acquire Deeside Aluminium: Oslo, Norway, Norsk Hydro ASA press release, July 25, 1 p.
———2000d, Hydro to operate Swiss remelter: Oslo, Norway, Norsk Hydro ASA press release, December 12, 1 p.
———2000e, New remelt plant in Spain: Oslo, Norway, Norsk Hydro ASA press release, September 20, 1 p.
———2000f, Venezuela casthouse joins Hydro supply chain: Oslo, Norway, Norsk Hydro ASA press release, November 9, 1 p.
———2001a, Annual report—2000: Oslo, Norway, Norsk Hydro ASA, 112 p.
———2001b, Sunndal expansion plans confirmed: Oslo, Norway, Norsk Hydro ASA press release, June 13, 2 p.
Ormet Primary Aluminum Corp., 2000a, Ormet announces complete potline restart scheduled for September: Wheeling, WV, Ormet Primary Aluminum Corp. press release, August 7, 2 p.
———2000b, Ormet announces plans to curtail aluminum production; sell power and alumina: Wheeling, WV, Ormet Primary Aluminum Corp. press release, May 18, 2 p.
———2000c, Ormet curtails Hannibal carbon operations: Wheeling, WV, Ormet Primary Aluminum Corp. press release, December 15, 2 p.
Pechiney, 2000a, Pechiney and AMP Life Limited exchange irrevocable offers for Pechiney to acquire AMP Life's 15.5% direct stake in the Tomago aluminum smelter: Paris, Pechiney press release, October 3, 1 p.
———2000b, PSA Peugeot Citroën and Pechiney sign a strategic partnership agreement: Paris, Pechiney press release, June 22, 1 p.
Pinkham, Myra, 2000, New aluminum-air fuel cell outlasts other power sources: American Metal Market, v. 108, no. 171, September 4, p. 11.
Platt's Metals Week, 2000a, ABI union accepts new offer: Platt's Metals Week, v. 71, no. 28, July 10, p. 13-14.
———2000b, Alcan to start up recycling furnace, primary capacity: Platt's Metals Week, v. 71, no. 20, May 15, p. 3-4.
———2000c, Asahan runs at 85-90% capacity: Platt's Metals Week, v. 71, no. 46, November 13, p. 5.
———2000d, Ball to close Salisbury aluminum can plant, cut others: Platt's Metals Week, v. 71, no. 23, June 5, p. 14-15.
———2000e, Baotou to build new aluminum line: Platt's Metals Week, v. 71, no. 45, November 6, p. 5.
———2000f, Butler Manufacturing to build aluminum extrusion plant: Platt's Metals Week, v. 71, no. 1, January 3, p. 6-7.
———2000g, Capral completes sales of Kurri Kurri: Platt's Metals Week, v. 71, no. 43, October 23, p. 5.
———2000h, Caradon/Indalex to buy Columbia plants, expand: Platt's Metals Week, v. 71, no. 18, p. 4-5.
———2000i, Crown Cork & Seal rebuilding struggling can businesses: Platt's Metals Week, v. 71, no. 49, December 4, p. 8.
———2000j, EC forces rethink of Alcan-Pechiney merger plan: Platt's Metals Week, v. 71, no. 12, March 20, p. 1, 10-11.
———2000k, Indalex grows Al extrusions despite slowdown in demand: Platt's Metals Week, v. 71, no. 47, November 20, p. 3-4.
———2000l, McCook to produce billet: Platt's Metals Week, v. 71, no. 11, March 13, p. 11.
———2000m, Nichols must keep Lupton focus: Platt's Metals Week, v. 71, no. 1, January 3, p. 7.
———2000n, Nikolaev stake winner close; smelter may be built: Platt's Metals Week, v. 71, no. 13, March 27, p. 7.
———2000o, Noranda Aluminum expansions make slow steady progress:

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Platt's Metals Week, v. 71, no. 13, March 27, p. 7-8.
———2000p, Superior to start up new furnace: Platt's Metals Week, v. 71, no. 24, June 12, p. 12.
———2000q, Taiyuan begins expansion construction: Platt's Metals Week, v. 71, no. 43, October 23, p. 5.
———2000r, Ukraine fails to sell alumina stake: Platt's Metals Week, v. 71, no. 48, November 27, p. 7-8.
———2000s, Ukraine to invest in new smelter: Platt's Metals Week, v. 71, no. 45, November 6, p. 4.
———2000t, Xiezhou's 40,000mt ready: Platt's Metals Week, v. 71, no. 27, July 3, p. 8.
———2000u, Yunnan faces expansion delays: Platt's Metals Week, v. 71, no. 24, June 12, p. 11.
———2000v, Zunyi begins expansion: Platt's Metals Week, v. 71, no. 15, April 10, p. 9.
Raghuvanshi, Vivek, 2000, Hindalco starts expansion: American Metal Market, v. 108, no. 12, January 20, p. 4.
Regan, Bob, 2000a, Century Aluminum completes Mt. Holly deal: American Metal Market, v. 108, no. 70, April 12, p. 12.
———2000b, Ormet sets wage talks with USW: American Metal Market, v. 108, no. 139, July 20, p. 16.
Rio Tinto plc, 2001, Annual report and financial statements—2000: London, Rio Tinto plc, 136 p.
Southwire Co., 2000, Century and Southwire extend date for closing aluminum smelter acquisition: Carrollton, GA, Southwire Co. press release, November 16, 1 p.
Worden, Edward, 2000a, De-ox producer Keystone reportedly halts operations: American Metal Market, v. 108, no. 176, September 12, p. 10.
———2000b, Secondary aluminum smelter starts operating in Quebec: American Metal Market, v. 108, no. 125, June 29, p. 7.
———2000c, Wabash slashes capacity, Huron Valley closes plant: American Metal Market, v. 108, no. 187, September 27, p. 9.
Wrigley, Al, 2000a, Agreement gives Nemak control of Ford's WAP, EAP plants: American Metal Market, v. 108, no. 218, November 10, p. 4.
———2000b, Ford opens new aluminum casting plant: American Metal Market, v. 108, no. 146, July 31, p. 12.
———2000c, GM picks Nemak for aluminum castings: American Metal Market, v. 108, no. 186, September 26, p. 16.
———2000d, GM's plans for Precept give aluminum shot in the arm: American Metal Market, v. 108, no. 7, January 12, p. 6.
———2000e, Hayes plans to build aluminum casting foundry: American Metal Market, v. 108, no. 50, March 15, p. 6.
———2000f, Metals still ride high in drive for lighter autos: American Metal Market, v. 108, no. 38, February 28, p. 6.
———2000g, Nemak to supply castings for DaimlerChrysler engine: American Metal Market, v. 108, no. 49, March 14, p. 6.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Aluminum. Ch. in Mineral Commodity Summaries, annual.
Aluminum. Mineral Industry Surveys, monthly.
Aluminum and Bauxite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Bauxite and Alumina. Ch. in Mineral Commodity Summaries, annual.
Primary Aluminum Plants Worldwide, 1998.
U.S. Trade in Bauxite and Alumina. Mineral Industry Surveys, quarterly.
World Bauxite Resources, Professional Paper 1076-B, 1986.

Other

Alumina Plants Worldwide, U.S. Bureau of Mines, 1993.
Aluminum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Aluminum Association Inc. Aluminum Statistical Review, annual.
Bauxite Mines Worldwide, U.S. Bureau of Mines, 1994.

TABLE 1
SALIENT ALUMINUM STATISTICS 1/

(Thousand metric tons, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Primary production	3,577	3,603	3,713	3,779	3,668
Value (million dollars)	$5,630	$6,120	$5,360	$5,470	$6,030
Price (average cents per pound), U.S. market (spot)	71.3	77.1	65.5	65.7	74.6
Inventories (December 31):					
Aluminum industry 2/	1,860	1,860	1,930	1,870	1,550
LME stocks in U.S. warehouses 3/	33	8	13	14	(4/)
National Defense Stockpile	57	(4/)	--	--	--
Secondary recovery: 5/	3,310	3,550	3,440	3,690 r/	3,450
New scrap	1,730	2,020	1,950	2,120 r/	2,080
Old scrap	1,570	1,530	1,500	1,570 r/	1,370
Exports (crude and semicrude)	1,500	1,570	1,590	1,640	1,760
Imports for consumption (crude and semicrude)	2,810	3,080	3,550	4,000	3,910
Aluminum industry shipments 6/	8,330	8,880	9,260	9,840	9,840
Supply, apparent 7/	8,340	8,740	9,040	9,890 r/	9,610
Consumption, apparent 8/	6,610	6,720	7,090	7,770 r/	7,530
World production	20,800 r/	21,700 r/	22,600 r/	23,600 r/	24,000 e/

e/ Estimated. r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits, except "Primary production" and "Prices."
2/ Includes ingot, semifabricated material, and scrap. Data for 1996 through 1998 from Current Industrial Reports, Series M33-D, U.S. Department of Commerce, U.S. Census Bureau. Data for 1999 and 2000 from Aluminum Association Inc.
3/ Includes aluminum alloyed material.
4/ Less than 1/2 unit.
5/ Metallic recovery from purchased, tolled, or imported new and old scrap expanded for full industry coverage.
6/ Shipped to domestic industry.
7/ Defined as domestic primary metal production plus secondary recovery plus imports minus exports plus adjustments for Government and industry stocks changes.
8/ Apparent supply less recovery from purchased new scrap.

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TABLE 2
PRIMARY ANNUAL ALUMINUM PRODUCTION CAPACITY IN THE UNITED STATES, BY COMPANY 1/

Company	Yearend capacity (thousand metric tons) 1999	2000	2000 ownership
Alcan Aluminum Corp.:			
Sebree, KY	186	186	Alcan Aluminium Ltd., 100%.
Alcoa Inc.: 2/			
Alcoa, TN	210	210	Alcoa Inc., 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	300	300	Do.
Ferndale, WA (Intalco)	272	272	Alcoa Inc., 61%; Mitsui and Co. Ltd., 32%; YKK Corp., 7%
Frederick, MD (Eastalco)	174	174	Do.
Longview, WA 3/	204	204	Alcoa Inc., 100%
Massena, NY 3/	123	123	Do.
Massena, NY	125	125	Do.
Mount Holly, SC	215 r/	215	Alcoa Inc., 50.3%; Century Aluminum Co., 49.7%.
Rockdale, TX	315	315	Alcoa Inc., 100%.
Troutdale, OR 3/	121	121	Do.
Wenatchee, WA	220	220	Do.
Total	2,390 r/	2,390	
Century Aluminum Co.:			
Ravenswood, WV	168 r/	168	Century Aluminum Co., 100%.
Columbia Falls Aluminum Co.:			
Columbia Falls, MT	168	168	Glencore AG, 100%
Goldendale Aluminum Co.:			
Goldendale, WA	168	168	Private interest, 60%; employees, 40%.
Kaiser Aluminum & Chemical Corp.:			
Mead, WA (Spokane)	200	200	MAXXAM Inc., 100%.
Tacoma, WA	73	73	Do.
Total	273	273	
NSA:			
Hawesville, KY	237	237	Southwire Co., 100%.
Noranda Aluminum Inc.:			
New Madrid, MO	222 r/	222	Noranda Mines Ltd., 100%.
Northwest Aluminum Corp.:			
The Dalles, OR	82	82	Private interests, 100%.
Ormet Primary Aluminum Corp.:			
Hannibal, OH	255	257	Ormet Corp., 100%.
Vanalco Inc.:			
Vancouver, WA	116	116	Vanalco Inc., 100%.
Grand total	4,270	4,270	

r/ Revised.
1/ Data are rounded to no more three significant digits; may not add to totals shown.
2/ Individual plant capacities are U.S. Geological Survey estimates based on company reported total.
3/ Alcoa and Reynolds merged in June 2000.

TABLE 3
U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP, BY CLASS 1/ 2/

(Metric tons)

Class	Consumption	Calculated recovery: Aluminum	Calculated recovery: Metallic
1999:			
Secondary smelters	2,130,000 r/	1,450,000 r/	1,560,000 r/
Integrated aluminum companies	1,230,000	1,010,000	1,080,000
Independent mill fabricators	787,000	674,000	720,000
Foundries	101,000	85,300	91,300
Other consumers	8,880	8,810	8,810
Total	4,250,000 r/	3,230,000 r/	3,460,000 r/
Estimated full industry coverage	4,560,000 r/	3,450,000 r/	3,690,000 r/

See footnotes at end of table.

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TABLE 3–Continued
U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP, BY CLASS 1/ 2/

(Metric tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
2000:			
Secondary smelters	1,960,000	1,350,000	1,450,000
Integrated aluminum companies	1,060,000	873,000	930,000
Independent mill fabricators	800,000	689,000	736,000
Foundries	95,600	80,200	85,800
Other consumers	14,600	14,600	14,600
Total	3,940,000	3,010,000	3,220,000
Estimated full industry coverage	4,220,000	3,220,000	3,450,000

r/ Revised.
1/ Excludes recovery from other than aluminum-base scrap.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP AND SWEATED PIG IN 2000 1/ 2/

(Metric tons)

Class of consumer and type of scrap	Stocks, January 1	Net receipts 3/	Consumption	Stocks, December 31
Secondary smelters:				
New scrap:				
Solids	12,800 r/	300,000	294,000	18,300
Borings and turnings	7,950 r/	325,000	324,000	9,660
Dross and skimmings	4,260 r/	531,000	532,000	4,080
Other 4/	3,750 r/	222,000	222,000	3,060
Total	28,700 r/	1,380,000	1,370,000	35,100
Old scrap:				
Castings, sheet, clippings	6,650 r/	352,000	354,000	4,730
Aluminum-copper radiators	2,130 r/	20,600	21,000	1,710
Aluminum cans 5/	1,170 r/	88,200	88,000	1,350
Other 6/	5,930 r/	119,000	119,000	5,990
Total	15,900 r/	580,000	582,000	13,800
Sweated pig	465 r/	10,800	11,100	191
Total secondary smelters	45,100 r/	1,970,000	1,960,000	49,100
Integrated aluminum companies, foundries, independent mill fabricators, other consumers:				
New scrap:				
Solids	22,400	801,000	806,000	17,900
Borings and turnings	104	23,100	22,900	318
Dross and skimmings	131	8,480	8,470	137
Other 4/	9,690 r/	212,000	214,000	6,930
Total	32,400 r/	1,040,000	1,050,000	25,300
Old scrap:				
Castings, sheet, clippings	3,060	148,000	144,000	6,940
Aluminum-copper radiators	439	6,500	6,700	241
Aluminum cans	13,600 r/	750,000	737,000	26,900
Other 6/	22	29,800	29,800	22
Total	17,100 r/	935,000	918,000	34,100
Sweated pig	86	2,840	2,740	179
Total integrated aluminum companies, etc.	49,500 r/	1,980,000	1,970,000	59,600
All scrap consumed:				
New scrap:				
Solids	35,200 r/	1,100,000	1,100,000	36,200
Borings and turnings	8,050 r/	348,000	347,000	9,970
Dross and skimmings	4,400 r/	540,000	540,000	4,210
Other 4/	13,400 r/	433,000	437,000	9,990
Total	61,100 r/	2,420,000	2,420,000	60,400

See footnotes at end of table.

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TABLE 4--Continued
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP AND SWEATED PIG IN 2000 1/ 2/

(Metric tons)

Class of consumer and type of scrap	Stocks, January 1	Net receipts 3/	Consumption	Stocks, December 31
All scrap consumed--Continued:				
Old scrap:				
Castings, sheet, clippings	9,710 r/	500,000	498,000	11,700
Aluminum-copper radiators	2,570 r/	27,100	27,700	1,960
Aluminum cans	14,700 r/	838,000	825,000	28,300
Other 6/	5,960 r/	149,000	149,000	6,010
Total	33,000 r/	1,510,000	1,500,000	47,900
Sweated pig	551 r/	13,600	13,800	370
Total of all scrap consumed	94,600 r/	3,950,000	3,940,000	109,000

r/ Revised.
1/ Includes imported scrap. According to reporting companies, 24.5% of total receipts of aluminum-base scrap, or 974,000 metric tons, was received on toll arrangements.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes inventory adjustment.
4/ Includes data on foil, can stock clippings, and other miscellaneous.
5/ Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.
6/ Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

TABLE 5
PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES 1/

(Metric tons)

	1999		2000	
	Production	Net shipments 2/	Production	Net shipments 2/
Diecast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	24,700 r/	24,600 r/	30,600	30,200
380 and variations	424,000 r/	419,000 r/	515,000	526,000
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	31,300 r/	31,200 r/	127,000	126,000
No. 319 and variations	148,000 r/	139,000 r/	137,000	139,000
F-132 alloy and variations	38,100 r/	37,500 r/	30,400	30,200
Al-Mg alloys	639	639	639	639
Al-Zn alloys	2,520 r/	1,950 r/	2,240	2,930
Al-Si alloys (0.6% to 2.0% Cu)	2,020	2,020	2,020	2,020
Al-Cu alloys (1.5% Si, maximum)	924	924	2,290	2,290
Al-Si-Cu-Ni alloys	949	952	949	951
Other	712	761	1,320	1,350
Wrought alloys, extrusion billets	221,000 r/	221,000 r/	210,000	210,000
Miscellaneous:				
Steel deoxidation	(3/)	(3/)	(3/)	(3/)
Pure (97.0% Al)	(3/)	(3/)	(3/)	(3/)
Aluminum-base hardeners	3,470	3,480	3,470	3,470
Other 4/	125,000 r/	121,000 r/	122,000	124,000
Total	1,020,000 r/	1,000,000 r/	1,190,000	1,200,000
Less consumption of materials other than scrap:				
Primary aluminum	77,400 r/	XX	77,600	XX
Primary silicon	49,200 r/	XX	50,200	XX
Other	10,400 r/	XX	16,700	XX
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot 5/	887,000 r/	XX	1,040,000	XX

r/ Revised. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes inventory adjustment.
3/ Withheld to avoid disclosing company proprietary data; included with "Miscellaneous: Other."
4/ Includes other die-cast alloys.
5/ No allowance made for melt-loss of primary aluminum and alloying ingredients.

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TABLE 6
DISTRIBUTION OF END-USE SHIPMENTS OF ALUMINUM PRODUCTS
IN THE UNITED STATES, BY INDUSTRY 1/

Industry	1999 Quantity (thousand metric tons)	1999 Percent of grand total	2000 Quantity (thousand metric tons)	2000 Percent of grand total
Containers and packaging	2,320	20.7	2,260	20.4
Building and construction	1,470	13.1	1,450	13.1
Transportation	3,600	32.2	3,610	32.5
Electrical	739	6.6	770	6.9
Consumer durables	760	6.8	770	6.9
Machinery and equipment	661	5.9	679	6.1
Other markets	293	2.6	293	2.6
Total to domestic users	9,840	88.1	9,840	88.6
Exports e/	1,330	11.9	1,270	11.4
Grand total	11,200	100.0	11,100	100.0

e/ Estimated.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: The Aluminum Association Inc.

TABLE 7
U.S. NET SHIPMENTS OF ALUMINUM WROUGHT
AND CAST PRODUCTS, BY PRODUCERS 1/ 2/

(Thousand metric tons)

	1999	2000
Wrought products:		
Sheet, plate, foil	5,000 r/	4,840
Pipe, tube, extruded, shapes	1,640 r/	1,920
Rod, bar, wire, cable	549 r/	303
Forgings (including impacts)	108 r/	106
Powder, flake, paste	54	59
Total	7,360 r/	7,230
Castings:		
Sand	158	NA
Permanent and semipermanent mold	533	NA
Die	1,030	NA
Other	135	NA
Total	1,850	NA
Grand total	9,210	NA

r/ Revised. NA Not available.
1/ Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: The Aluminum Association Inc.; U.S. Department of Commerce.

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TABLE 8
U.S. EXPORTS OF ALUMINUM, BY COUNTRY 1/

Country or territory	Metals and alloys, crude		Plates, sheets, bars, etc. 2/		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:								
Azerbaijan	--	--	1	$3	--	--	1	$3
Brazil	110	$714	60,200	172,000	17	$96	60,300	173,000
Canada	145,000	225,000	489,000	1,180,000	162,000	149,000	795,000	1,560,000
France	143	541	6,990	30,900	85	129	7,220	31,500
Germany	1,610	6,900	5,640	32,200	90	279	7,340	39,400
Hong Kong	661	1,230	4,110	15,600	24,600	33,100	29,400	49,900
Italy	127	269	2,530	12,500	53	122	2,710	12,900
Japan	71,700	113,000	10,400	87,400	35,200	40,700	117,000	241,000
Korea, Republic of	798	2,440	16,700	53,100	29,300	29,100	46,800	84,600
Mexico	93,700	147,000	152,000	444,000	60,400	79,100	306,000	670,000
Netherlands	130	289	1,310	6,610	711	793	2,150	7,700
Philippines	14	65	536	2,460	296	98	847	2,620
Russia	5	73	9	85	--	--	14	158
Saudi Arabia	1	7	8,150	22,400	64	128	8,210	22,500
Singapore	111	575	1,850	13,200	1,290	1,750	3,250	15,500
Slovakia	--	--	9	54	--	--	9	54
Slovenia	--	--	55	128	3	12	58	140
South Africa	(3/)	8	327	1,930	(3/)	4	328	1,940
Taiwan	660	1,740	10,900	33,200	31,300	29,800	42,900	64,800
Thailand	106	205	3,900	14,400	92	135	4,100	14,700
Ukraine	--	--	(3/)	4	--	--	(3/)	4
United Kingdom	1,040	5,270	16,700	72,800	403	810	18,100	78,800
Venezuela	229	1,990	17,900	38,700	--	--	18,100	40,700
Other	2,640	7,610	98,500	330,000	73,500	80,000	175,000	418,000
Total	318,000	515,000	907,000	2,570,000	419,000	445,000	1,640,000	3,530,000
2000:								
Azerbaijan	--	--	--	--	--	--	--	--
Brazil	829	1,520	31,900	98,100	159	180	32,900	99,800
Canada	125,000	208,000	504,000	1,310,000	225,000	221,000	854,000	1,740,000
France	30	122	5,530	29,400	1,790	3,290	7,350	32,800
Germany	858	5,130	4,980	30,100	1,150	2,820	6,990	38,100
Hong Kong	1,440	2,420	2,610	13,000	28,900	34,400	33,000	49,900
Italy	33	111	2,070	12,000	8	11	2,110	12,100
Japan	44,300	74,400	9,840	74,400	27,800	35,500	81,900	184,000
Korea, Republic of	3,640	11,900	20,500	77,000	34,100	38,100	58,200	127,000
Mexico	87,700	140,000	156,000	523,000	78,000	105,000	321,000	768,000
Netherlands	244	1,020	3,280	12,900	415	621	3,940	14,500
Philippines	41	61	774	3,530	265	435	1,080	4,020
Russia	--	--	211	1,180	47	64	258	1,250
Saudi Arabia	1	11	8,380	20,300	2	6	8,380	20,300
Singapore	414	1,160	2,630	15,700	346	459	3,390	17,300
Slovakia	--	--	11	35	--	--	11	35
Slovenia	--	--	(3/)	4	--	--	(3/)	4
South Africa	24	220	80	919	15	68	118	1,210
Taiwan	2,200	3,540	8,430	31,000	30,300	31,500	40,900	66,000
Thailand	822	1,720	6,860	24,300	1,020	1,420	8,700	27,400
Ukraine	--	--	1	25	--	--	1	25
United Kingdom	1,090	3,770	20,400	94,700	5,450	5,910	26,900	104,000
Venezuela	63	125	17,200	40,200	33	117	17,300	40,500
Other	4,800	12,400	102,000	353,000	141,000	167,000	248,000	532,000
Total	273,000	468,000	907,000	2,770,000	576,000	648,000	1,760,000	3,880,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes castings, forgings, and unclassified semifabricated forms.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF ALUMINUM, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	318,000	$515,000	273,000	$468,000
Scrap	419,000	445,000	576,000	648,000
Plates, sheets, bars, strip, etc.	857,000	2,280,000	845,000	2,380,000
Castings and forgings	15,300	113,000	14,700	137,000
Semifabricated forms, n.e.c.	34,600	171,000	48,000	248,000
Total	1,640,000	3,530,000	1,760,000	3,880,000
Manufactures:				
Foil and leaf	65,000	211,000	61,100	219,000
Powders and flakes	8,320	35,800	9,600	47,500
Wire and cable	33,100	127,000	29,500	122,000
Total	106,000	374,000	100,000	388,000
Grand total	1,750,000	3,900,000	1,860,000	4,270,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	2,650,000	$3,760,000	2,490,000	$4,030,000
Plates, sheets, strip, etc., n.e.c. 2/	593,000	1,330,000	628,000	1,530,000
Pipes, tubes, etc.	24,100	98,100	20,800	109,000
Rods and bars	118,000	349,000	142,000	449,000
Scrap	615,000	666,000	625,000	744,000
Total	4,000,000	6,200,000	3,910,000	6,860,000
Manufactures:				
Foil and leaf 3/	89,900	271,000	87,800	293,000
Flakes and powders	3,560	10,100	5,020	14,000
Wire	97,600	172,000	118,000	231,000
Total	191,000	452,000	211,000	538,000
Grand total	4,190,000	6,660,000	4,120,000	7,400,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes plates, sheets, circles, and disks.
3/ Excludes etched capacitor foil.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY 1/

Country	Metals and alloys, crude Quantity (metric tons)	Metals and alloys, crude Value (thousands)	Plates, sheets, bars, etc. 2/ Quantity (metric tons)	Plates, sheets, bars, etc. 2/ Value (thousands)	Scrap Quantity (metric tons)	Scrap Value (thousands)	Total Quantity (metric tons)	Total Value (thousands)
1999:								
Argentina	22,400	$32,200	1,330	$2,330	3,990	$5,110	27,700	$39,700
Australia	60,900	89,700	2,050	4,220	9	14	63,000	94,000
Bahrain	22,700	32,300	26,600	48,400	--	--	49,200	80,700
Belgium	20	468	4,050	11,900	198	197	4,260	12,600
Brazil	56,700	74,100	1,720	3,450	33,100	37,800	91,500	115,000
Canada	1,500,000	2,210,000	427,000	943,000	287,000	314,000	2,210,000	3,460,000

See footnotes at end of table.

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TABLE 11--Continued
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY 1/

Country	Metals and alloys, crude		Plates, sheets, bars, etc. 2/		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999--Continued:								
Croatia	--	--	273	$933	--	--	273	$933
Czech Republic	83	$106	591	1,740	40	$45	714	1,890
France	492	4,960	11,800	53,500	11,500	10,400	23,900	68,900
Germany	813	4,490	38,900	146,000	6,810	10,100	46,500	161,000
Italy	2,130	2,530	3,030	9,780	518	581	5,670	12,900
Japan	429	942	23,600	80,100	816	929	24,800	82,000
Korea, Republic of	--	--	21,400	42,300	--	--	21,400	42,300
Mexico	2,460	4,280	17,700	56,100	86,100	90,700	106,000	151,000
Netherlands	1,280	2,070	3,490	10,400	10,700	13,100	15,400	25,600
Norway	3,280	6,270	1,610	2,830	140	142	5,030	9,240
Panama	367	650	1,230	3,340	5,820	6,390	7,420	10,400
Russia	711,000	939,000	54,700	96,800	65,300	68,600	831,000	1,100,000
Slovakia	203	216	1	2	--	--	204	218
Slovenia	--	--	4,000	11,800	--	--	4,000	11,800
South Africa	18,300	24,000	4,070	10,400	169	144	22,500	34,500
Spain	273	427	3,230	7,360	2,100	2,370	5,600	10,200
Tajikistan	17,200	20,600	--	--	--	--	17,200	20,600
Ukraine	26,600	30,600	(3/)	10	5,510	6,310	32,200	36,900
United Arab Emirates	17,800	25,100	--	--	3,240	3,130	21,000	28,300
United Kingdom	10,900	14,300	15,100	56,000	19,500	21,000	45,500	91,300
Venezuela	127,000	178,000	16,800	29,100	26,000	29,500	169,000	236,000
Other	53,000	69,700	51,200	143,000	46,500	45,300	151,000	258,000
Total	2,650,000	3,760,000	735,000	1,770,000	615,000	666,000	4,000,000	6,200,000
2000:								
Argentina	59,000	100,000	1,360	2,950	1,300	1,710	61,700	105,000
Australia	23,000	38,800	2,840	6,300	--	--	25,800	45,100
Bahrain	22,000	37,300	22,000	45,100	103	49	44,100	82,500
Belgium	21	97	3,690	11,600	99	120	3,810	11,800
Brazil	42,800	69,700	9,810	17,200	32,900	48,900	85,500	136,000
Canada	1,420,000	2,390,000	435,000	1,050,000	289,000	345,000	2,150,000	3,780,000
Croatia	--	--	163	547	--	--	163	547
Czech Republic	21	29	307	1,040	--	--	328	1,070
France	869	8,230	10,400	43,200	11,400	9,820	22,700	61,300
Germany	643	4,810	41,700	163,000	6,740	8,380	49,100	176,000
Italy	200	265	2,980	10,700	35	44	3,220	11,000
Japan	336	787	21,400	80,500	753	1,360	22,500	82,700
Korea, Republic of	89	274	13,300	33,900	514	1,050	13,900	35,200
Mexico	4,570	6,670	22,000	79,000	76,000	85,800	102,000	171,000
Netherlands	218	626	4,200	13,000	2,510	2,620	6,930	16,300
Norway	7,010	13,500	106	418	--	--	7,110	14,000
Panama	12	14	1,480	4,710	7,200	9,040	8,690	13,800
Russia	670,000	996,000	66,500	159,000	100,000	122,000	837,000	1,280,000
Slovakia	255	273	2	9	--	--	257	282
Slovenia	--	--	4,350	14,000	--	--	4,350	14,000
South Africa	24,000	36,400	23,300	53,500	599	660	47,900	90,600
Spain	343	644	402	1,630	161	205	905	2,470
Ukraine	10,200	12,600	--	--	6,830	7,240	17,000	19,800
United Arab Emirates	53,300	94,900	--	--	4,990	6,080	58,300	101,000
United Kingdom	5,290	8,210	15,400	60,700	5,650	6,340	26,300	75,200
Venezuela	120,000	165,000	24,900	47,900	19,800	23,300	165,000	236,000
Other	25,800	42,400	63,700	187,000	58,400	64,200	148,000	293,000
Total	2,490,000	4,030,000	791,000	2,080,000	625,000	744,000	3,910,000	6,860,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes circles, disks, rods, pipes, tubes, etc.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 12
ALUMINUM, PRIMARY: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Argentina	184	187	187	205 r/	260
Australia	1,372	1,495	1,627	1,718	1,769 3/
Azerbaijan	1	5	-- e/	-- e/	--
Bahrain	461	490	501 r/	503 r/	509 3/
Bosnia and Herzegovina e/ 4/	10	15	28 r/	70 r/	90
Brazil	1,195	1,200	1,208	1,250	1,277 3/
Cameroon e/	82	91	82 r/	92 r/	95
Canada	2,283	2,327	2,374	2,390	2,373 3/
China e/	1,770	1,960	2,340	2,530 r/	2,550
Croatia e/ 4/	38 3/	35	35	35	35
Egypt	179	178	195 r/	193 r/	193
France	380	399 e/	424	455 r/	441 3/
Germany	576	572	612	634 r/	644 3/
Ghana	137	152	56 e/	104 r/	156 3/
Greece	141	133	146	160 r/	163 3/
Hungary e/	30 3/	35	35	35	35
Iceland 5/	104	123	173 r/	220 r/	224 3/
India 6/	531	484	542	550 e/	560
Indonesia e/ 6/	225	216 3/	130	100	160
Iran	80 r/	92 r/	124 r/	137 r/	140
Italy	184	188	188 e/	187 r/	189 3/
Japan 7/	17	17	16 r/	11 r/	7 3/
Mexico 6/	61	66	62	67 r/	66
Mozambique	--	--	--	--	54
Netherlands	227	232	264 e/	287 r/	300
New Zealand	283 r/	310 r/	318 r/	327 r/	325
Nigeria e/	-- 3/	3	20	16	--
Norway	863	919	996	1,020 r/	1,026 3/
Poland 8/	52	54	54	55 e/	55
Romania 9/	141	163	170 r/	174 r/	175
Russia	2,874	2,906	3,005	3,146	3,245 3/
Serbia and Montenegro 4/	37	66	61 r/	73 r/	70
Slovakia 6/	111 r/	110 r/	108 r/	109 r/	110 3/
Slovenia e/ 4/	60	60	50 e/	50	50
South Africa	570	673	677 r/	679 r/	671 3/
Spain	362	360	362	364 r/	366 3/
Suriname e/	32 3/	32	29	10	--
Sweden	98	98	96 e/	99 r/	101 3/
Switzerland	27	27	32	34 r/	35
Tajikistan	198	206 r/	196	229	300 3/
Turkey	60	62	62	62	60
Ukraine	90 e/	101	107	112	104 3/
United Arab Emirates	259	378	387	440 e/	500
United Kingdom	240	248	258	272	305 3/
United States	3,577	3,603	3,713	3,779	3,668 3/
Venezuela	629	634	585 r/	570	570
Total	20,800 r/	21,700 r/	22,600 r/	23,600 r/	24,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Primary aluminum is defined as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through May 11, 2001.

3/ Reported figure.

4/ Primary ingot plus secondary ingot.

5/ Ingot and rolling billet production.

6/ Primary ingot.

7/ Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1996--29,351; 1997--36,136; 1998--35,063; 1999--34,893 (revised); and 2000--40,956.

8/ Primary unalloyed ingot plus secondary unalloyed ingot.

9/ Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

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ANTIMONY

By James F. Carlin, Jr.

Domestic survey data and tables were prepared by Evangeline J. Hemphill, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

About one-half of the primary antimony used in the United States went into flame-retardants; most of the remainder was used by the transportation, chemical, ceramics, and glass industries. Secondary antimony, which was derived almost entirely from recycled lead-acid batteries, was used in the manufacture of new batteries. The price of antimony metal, on average, was almost 5% higher than that of 1999. World production rose 9%.

A small amount of antimony was recovered as a byproduct of the mining of silver-copper ores at one mine in Idaho, but almost all primary antimony metal and oxide produced domestically originated from raw material imports. Primary smelter production declined 12%. Most domestic smelting consisted of upgrading imported antimony trioxide to a higher purity. Primary antimony metal and oxide, valued at $41 million, were produced by four companies operating four plants—two in Texas and one each in Montana and New Jersey. One of these primary smelters ceased production permanently during the year. Secondary antimony was recovered from scrapped lead-acid batteries at secondary lead smelters. The amount of antimony used by battery manufacturers is substantially lower than it was 10 years ago because of changing materials requirements for batteries. Industry stocks declined slightly (table 4).

Antimony was mined as a principal product and was a byproduct of the smelting of base-metal ores in 15 countries. Ninety-five percent of world primary antimony was mined in China (85%), South Africa (4%), Russia (4%), and Bolivia (2%) (table 9). World antimony reserves were estimated to be 2.1 million metric tons (Carlin, 2001).

Legislation and Government Programs

Sales of antimony from the National Defense Stockpile (NDS) proceeded for the eighth consecutive year. Sales were conducted on a negotiated bid basis and were held by Defense National Stockpile Center (DNSC) on the third Monday of each month. There was no maximum limit on the quantity for which a company could submit a bid, but the minimum quantity allowed was 18,144 kilograms (40,000 pounds). The materials offered were grade A and grade B ingots, cake, and broken pieces. All antimony sulfide ore held in the NDS has been sold. In calendar year 2000, 4,536 metric tons (t) of antimony was sold. At yearend 2000, the antimony inventory in the DNSC was 8,275 t. Antimony was stockpiled in Government warehouses at three depots, with Somerville, NJ, holding the largest amount (Defense Logistics Agency, 2000).

Production

Mine.—In the Coeur d'Alene District of Idaho, Sunshine Mining Co., the sole domestic antimony producer, recovered antimony-in-concentrate as a byproduct of the treatment of complex silver-copper-antimony sulfide ore. The company answered the U.S. Geological Survey (USGS) production survey for 2000; output data are not published, however, in order to protect company proprietary information.

Smelter.—The domestic producers of primary antimony metal and oxide products were Amspec Chemical Corp., Gloucester City, NJ; Anzon Inc., Laredo, TX; Laurel Industries Inc., La Porte, TX; and U.S. Antimony Corp., Thompson Falls,

Antimony in the 20th Century

In 1900, the amount of antimony obtained from domestic ores (about 200 metric tons) was just a small fraction of the amount consumed in the United States. A moderate amount (about 1,500 tons) of antimony ore was imported and smelted in the country. But even these sources together comprised only about one-half of the total amount of antimony consumed domestically. The balance came from crude antimony in various forms that was imported for smelting. Sources of the imported antimony materials are unknown. In 1900, alloying was the major domestic use of antimony. Perhaps foremost among antimony alloys was an alloy of the metal and lead, which was widely used in the manufacture of printing type metal. Antimony imparted hardness to the alloy and had the property of expanding at the moment of solidifying, thus giving to the type a clean, sharp face. Some antimony was used in the making of babbitt metal, an antifriction alloy used in moving parts for railroad locomotives. Early in the century, pewter contained 7% antimony. A small amount of antimony was used in medicines. Total antimony consumption in 1900 in the United States was about 3,000 tons.

In 2000, the amount of antimony obtained from domestic ores (about 400 tons) was only a minuscule fraction of the antimony used in the United States. Antimony ores and crude antimony imported and smelted in the United States satisfied the bulk of the country's needs. Idaho was the only State producing antimony-in-concentrate as a byproduct of treating complex silver-copper-antimony sulfide ore. Four domestic antimony smelters processed various forms of antimony mostly into antimony trioxide used primarily for flame-retardant chemicals. Flame-retardant chemicals were a new use for antimony starting in the early 1970s and experienced strong growth since that time under the impetus of fire safety concerns about clothing for infants, plastic toys, automobile and aircraft seat covers, etc. China, the world's leading antimony producer in 2000, was the major foreign source of antimony trioxide for the United States. Total antimony use in 2000 in the Nation was about 16,700 tons.

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MT. The Anzon facility closed permanently near yearend. All replied to the USGS request for production data.

Secondary.—Old scrap, mostly lead battery plates, was the predominant source of the secondary antimony output. New scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. Antimonial lead was the main market for scrap antimony.

Consumption

Reported consumption of primary antimony in 2000 was 24% above that in 1999. Flame-retardants, especially plastics, accounted for most of the increase. Lead-antimony alloys were used in automotive vehicle batteries, ammunition, corrosion-resistant pumps and pipes, tank linings, roofing sheet solder, cable sheaths, and antifriction bearings. Antimony trioxide, often dissolved in an organic solvent, was used to enhance the flame-retardant properties of plastics, rubber, textiles, and other combustibles. Antimony also was used as a decolorizing and refining agent in some forms of glass such as optical glass.

Of the 164 companies to which a USGS consumption survey was sent, 140 firms responded. Consumption data were estimated for the remaining 24 firms.

Prices

In 2000, antimony prices varied within a fairly narrow range, starting and ending the year at about the same level. The New York dealers' antimony metal price, published by Platt's Metals Week, started the year at $0.63 to $0.70 per pound and finished the year at $0.68 to $0.73 per pound. This price averaged $0.66 per pound for the year compared with $0.63 per pound in 1999. This small increase was the first after 3 years of relatively large decreases. The price range for high-tint antimony trioxide, published by American Metal Market, was $0.90 to $1.05 per pound at the start of the year and $0.89 to $1.25 per pound at the end of the year.

Trade

Imports of antimony were, as is usually the case, much larger than exports—about five-fold larger in 2000 (tables 5-8). Imports rose slightly, with the categories of ore/concentrate and oxide registering the only gains. Australia emerged as the largest supplier of antimony ore and concentrate, accounting for 38% of the total. China remained the dominant provider of antimony metal and antimony oxide, supplying 88% of the former, and 47% of the latter.

Exports of metal alloys, waste and scrap more than doubled. Exports of antimony oxide almost doubled.

World Review

Bolivia.—The privatization sale of Corporacíon Minera de Bolivia's shuttered Vinto antimony smelting plant was concluded with a $1.1 million offer from Colquiri SA, a subsidiary of Bolivia's biggest mining organization, Corporacíon Minera de Sur. Colquiri's bid was backed by the Commonwealth Development Corp. Ltd. (UK) and exceeded by 11 times the $100,000 base price set by Banque Parbas, the Government's advisor for the sale (Metal Bulletin, 2000a).

China.—Reports in 2000 indicated that China's Government intended to further limit the export of antimony products. The aim of this policy was to hold exports to 60,000 t in 2000 compared with the official quota of 80,000 t in each of the previous 2 years. The Ministry of Foreign Trade and Economic Cooperation indicated that no new export licences were to be granted until 2001.

Government officials believed that smuggling of antimony, which in previous years accounted for a significant tonnage of antimony shipped abroad, had been virtually eliminated due to greater efforts against illegal shipments. Officials also projected domestic Chinese antimony consumption at 10,000 t in 2000 (Metal Bulletin, 2000b).

The Huan Dong Metal Materials Plant in Guangxi announced plans to produce 10,000 t of antimony trioxide in 2000, up 25% from 1999 output. Guangxi accounts for about 80% of China's antimony output (Platt's Metals Week, 2000a).

The Guangxi Nandan Longquan Mining and Smelting Works completed an expansion that began a year earlier, doubling ore handling capacity from 2,400 metric tons per day (t/d) to 4,800 t/d. Longquan, which previously had the capacity to produce 6,000 metric tons per year (t/yr) of antimony ingot, reached a capacity of 15,000 t/yr. The cost of the expansion project was estimated at $12 million. Longquan accumulated 100,000 t of antimony concentrate for processing in its smelter. Its antimony ingot output in 1999 was 3,500 t; an output of 7,000 t was expected in 2000 (Platt's Metals Week, 2000b).

Outlook

Domestic antimony consumption, especially for important uses such as flame retardants, is likely to remain strong for the near future. A few new antimony mines have been developed in recent years (in Canada, for example) but continuing low antimony prices will probably prevent them from coming fully on-stream any time soon. The NDS will be selling antimony for a few more years, thus remaining as a small but readily available part of domestic supply.

References Cited

Carlin, J.F., Jr., 2001, Antimony: U.S. Geological Survey Mineral Commodity Summaries 2001, p. 20-21.

Defense Logistics Agency, 2000, Inventory of stockpile material: Fort Belvoir, VA, Defense Logistics Agency monthly release, December 31, p. 1.

Metal Bulletin, 2000a, Comsur-CDC buys Vinto antimony plant for $1.1m: Metal Bulletin, no. 8528, November 23, p. 7.

———2000b, Minmetals confirms antimony export cuts and industry shake-up: Metal Bulletin, no. 8491, July 10, p. 9.

Platt's Metals Week, 2000a, China's Huan Dong to up antimony trioxide output: Platt's Metals Week, v. 71, no. 13, March 27, p. 15.

———2000b, China's Longquan boosts Sb capacity: Platt's Metals Week, v. 71, no. 48, November 27, p. 5.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Antimony. Ch. in Minerals Yearbook, annual.
Antimony. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Antimony. Mineral Industry Surveys, quarterly.

Other

American Metal Market, daily.
Antimony. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Engineering and Mining Journal.
Metal Bulletin [London].

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TABLE 1
SALIENT ANTIMONY STATISTICS 1/

(Metric tons of antimony content unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production, primary:					
Mine (recoverable antimony)	242 2/	356 2/	489 r/ 2/	450 r/ 2/	W
Smelter	25,600	26,400	24,000	23,800	20,900
Production, secondary	7,780	7,550	7,710	8,220	7,920
Exports of metal, alloys, waste and scrap (gross weight)	462	652	898	473	1,080
Exports of antimony oxide 3/	3,990	3,230	3,270	3,190	6,040
Imports for consumption	37,600	39,300	34,600	36,800	41,600
Reported industrial consumption, primary antimony	13,600	13,500	12,700	13,500 r/	16,700
Stocks, primary antimony, all classes, December 31	11,000	10,800	10,600	10,900 r/	10,300
Price, average 4/ cents per pound	146.5	97.8	71.8	62.7	65.5
World, mine production	156,000 r/	155,000	117,000	108,000 r/	118,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Data from 10-K reports.

3/ Antimony content is calculated by the U.S. Geological Survey.

4/ New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.

TABLE 2
REPORTED INDUSTRIAL CONSUMPTION OF
PRIMARY ANTIMONY IN THE UNITED STATES 1/

(Metric tons of antimony content)

	Class of material consumed			
Year	Metal	Oxide	Other 2/	Total
1999	1,570	11,800 r/	178	13,500 r/
2000	1,800	14,800	100	16,700

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes residues and sulfide.

TABLE 3
REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY
ANTIMONY IN THE UNITED STATES, BY PRODUCT 1/

(Metric tons of antimony content)

Product	1999	2000
Metal products:		
Antimonial lead	1,110 r/	864
Bearing metal and bearings	29 r/	42
Solder	136 r/	136
Other 2/	1,170 r/	1,660
Total	2,440	2,700
Nonmetal products:		
Ammunition primers	23	26
Ceramics and glass	1,120	862
Pigments	1,020	620
Plastics	1,580	1,960
Other 3/	198	647
Total	3,940	4,110
Flame retardants:		
Adhesives	140	332
Plastics	6,370 r/	8,920
Rubber	391	382
Textiles	229	221
Other 4/	14	70
Total	7,140 r/	9,930
Grand total	13,500 r/	16,700

See footnotes at end of table.

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TABLE 3--Continued
REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY ANTIMONY IN THE UNITED STATES, BY PRODUCT 1/

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes ammunition, cable covering, castings, sheet and pipe, and type metal.
3/ Includes fireworks and rubber products.
4/ Includes paper and pigments.

NOTE: Secondary antimonial lead was 4,410 in 1999 and 5,690 in 2000.

TABLE 4
INDUSTRY STOCKS OF PRIMARY ANTIMONY IN THE UNITED STATES, DECEMBER 31 1/

(Metric tons of antimony content)

Type of material	1999	2000
Metal	2,430	2,570
Oxide	5,780 r/	4,880
Other 2/	2,720	2,860
Total	10,900 r/	10,300

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes ore and concentrate, residues, and sulfide.

TABLE 5
U.S. EXPORTS OF ANTIMONY METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY 1/

	1999		2000	
Country	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Brazil	9	$16	--	--
Canada	153	302	274	$525
Chile	--	--	6	16
Colombia	--	--	10	16
El Salvador	20	34	10	17
Japan	24	235	10	119
Korea, Republic of	--	--	40	48
Mexico	230	508	721	1,630
Switzerland	6	45	1	21
Thailand	24	494	2	72
Other	6	176	4	355
Total	473	1,810	1,080	2,820

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. EXPORTS OF ANTIMONY OXIDE, BY COUNTRY 1/

	1999			2000		
Country	Gross weight (metric tons)	Antimony content 2/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Antimony content 2/ (metric tons)	Value (thousands)
Argentina	94	78	$293	115	95	$302
Australia	196	163	463	128	106	254
Belgium	1	1	5	13	11	40
Brazil	19	16	73	98	81	386
Canada	1,420	1,180	3,280	1,730	1,440	3,930
China	376	312	1,140	134	111	264
Colombia	174	144	389	118	98	214

See footnotes at end of table.

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TABLE 6--Continued
U.S. EXPORTS OF ANTIMONY OXIDE, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Antimony content 2/ (metric tons)	1999 Value (thousands)	2000 Gross weight (metric tons)	2000 Antimony content 2/ (metric tons)	2000 Value (thousands)
France	57	47	$158	50	42	$130
Germany	119	99	420	102	85	438
Indonesia	36	30	91	--	--	--
Italy	1	1	6	--	--	--
Japan	90	75	216	130	108	509
Korea, Republic of	27	22	138	55	46	135
Mexico	688	571	1,670	3,820	3,170	5,680
Singapore	75	62	176	77	64	158
Spain	78	65	274	48	40	181
Taiwan	23	19	69	29	24	78
Turkey	47	39	146	62	51	189
United Kingdom	218	181	703	402	334	834
Other	108 r/	89 r/	331 r/	151	125	463
Total	3,840	3,190	10,000	7,280	6,040	14,200

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Antimony content is calculated by the U.S. Geological Survey.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY, BY CLASS AND COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Antimony content 2/ (metric tons)	1999 Value (thousands)	2000 Gross weight (metric tons)	2000 Antimony content 2/ (metric tons)	2000 Value (thousands)
Antimony ore and concentrate:						
Australia	1,660	1,070	$710	1,750	1,150	$751
Austria	95	66	307	140	98	392
Bolivia	--	--	--	220	144	101
China	436	398	508	1,000	1,000	1,550
France	--	--	--	6	3	18
Hong Kong	59	53	52	62	60	65
Mexico	1,340	1,290	1,770	937	903	1,170
Russia	--	--	--	499	315	193
Thailand	--	--	--	20	16	12
Total	3,590	2,870	3,350	4,630	3,690	4,250
Antimony oxide:						
Belgium	3,290	2,730	5,890	3,690	3,070	6,560
Bolivia 3/	1,770	1,470	2,110	1,150	957	1,220
Chile 3/	275	229	328	--	--	--
China	9,470	7,860	11,800	13,100	10,900	17,300
France	233	193	329	66	54	230
Germany	16	14	277	47	39	802
Guatemala	249	207	428	77	64	132
Hong Kong	420	349	523	453	376	622
Japan	127	105	700	33	27	274
Kyrgyzstan	--	--	--	224	186	247
Mexico	3,560	2,950	4,710	5,530	4,590	7,660
Netherlands	178	148	193	--	--	--
South Africa	3,220	2,680	938	3,830	3,180	999
Taiwan	--	--	--	29	24	53
Thailand	--	--	--	60	50	11
United Kingdom	244	202	699	176	146	298
Total	23,100	19,100	28,900	28,500	23,700	36,500

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Antimony ore and concentrate content reported by the U.S. Census Bureau. Antimony oxide content is calculated by the U.S. Geological Survey.
3/ Antimony oxide from these countries believed to be "crude" and would probably be shipped to refineries for upgrading.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY METAL, BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Bolivia	(2/)	(2/)	100	$145
Canada	58	$303	62	274
China	13,100	15,800	12,500	16,400
Germany	(2/)	167	(2/)	114
Hong Kong	267	270	206	222
Japan	10	481	14	498
Kyrgyzstan	(2/)	(2/)	41	53
Mexico	736	524	801	555
Peru	209	219	210	275
Singapore	400	439	300	316
Taiwan	(2/)	11	--	--
United Kingdom	(2/)	204	--	--
Other	9	10	11	271
Total	14,800	18,500	14,200	19,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
ANTIMONY: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Australia 3/	1,800	1,900	1,800	2,300 r/	1,800
Bolivia	6,488	5,999	4,735	2,790 r/	2,800
Canada 4/	1,716	529	428	357 r/	364 5/
China e/	129,000	131,000	97,400	89,600 r/	100,000
Guatemala	880	880	440	440 e/	450
Honduras	400	300	-- e/	-- e/	--
Kyrgyzstan e/	1,200	1,200 5/	150	100	150
Mexico 6/	983	1,909	1,301	273 r/	52 p/
Morocco e/ 4/	152 5/	160	160	150	150
Namibia (Sb content of sodium antimonate)	8	--	-- e/	-- e/	--
Peru (recoverable) e/	460	460	460	460	460
Russia (recoverable) e/	6,000	6,000	4,000	4,000	4,500
South Africa 4/	5,137	3,415	4,243	5,278 r/	5,000
Tajikistan e/	1,000	1,200 5/	1,500	1,800	2,000
Thailand (content of ore and concentrate)	63 r/	53 r/	199 r/	59 r/	84 5/
Turkey	285	31	30 e/	180 r/ e/	360
United States	242	356	489 r/	450 r/	W
Zimbabwe 4/	5 e/	--	--	--	--
Total	156,000 r/	155,000	117,000	108,000 r/	118,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Antimony content of ore unless otherwise indicated. Table includes data available through June 8, 2001.
3/ Antimony content of antimony ore and concentrate, lead concentrates, and lead-zinc concentrates.
4/ Antimony content of concentrate.
5/ Reported figure.
6/ Antimony content of antimonial lead, natural minerals, and other smelter products produced.

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ARSENIC

By Robert G. Reese, Jr.

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

As has been the case since 1985, the United States had no domestic production of arsenic in 2000 and, consequently, remained dependent on imports to meet its arsenic needs. Although the United States imported some arsenic metal, most domestic arsenic imports were in compound form, primarily arsenic trioxide. China remained the principal supplier of arsenic and its compounds to the U.S. market.

Legislation and Government Programs

The U.S. Geological Survey (USGS) in 2000 was directly involved in a broad range of national and international studies related to arsenic and its distribution and mobility in the environment. Activities included data collection, long-term assessments, ecosystem analysis, predictive modeling, and process research on the occurrence, distribution, transport, and fate of arsenic as well as the impacts of contaminants on biota. Much of this work was conducted in partnership with other Federal and State agencies.

The location and extent of arsenic occurrence in ground water across the United States was the subject of a USGS map published in 2000 (Focazio and others, 2000). The presence of arsenic in ground water is largely due to minerals dissolving naturally over time as rocks and soils weather. Data on nearly 19,000 samples of potable ground water used to develop the map indicated that the arsenic concentration was nearly always lower than the U.S. Environmental Protection Agency (EPA) standard of 50 micrograms per liter. Additionally, the USGS found that approximately 10% of the samples exceeded the more stringent World Health Organization standard of 10 micrograms per liter. At yearend, the EPA was in the process of designating a new drinking water standard for arsenic.

Additionally, the USGS published a map showing the distribution of arsenic in the Warrior coalfield in Alabama (Goldhaber and others, 2000). Using data from over 900 chemical analyses contained in the USGS National Coal Resources Data System, the authors found that the Warrior field contained higher levels of arsenic and a suite of other trace elements when compared to the average for all U.S. coal. The map used three-dimensional plots of Warrior coalbeds to show arsenic abundance and concentration.

Consumption

Trade data indicated that the United States, with an estimated demand of more than 24,000 metric tons (t) in 2000, probably remained the world's largest consumer of arsenic. The estimated value of arsenic consumed domestically during the year was approximately $25 million. More than 95% of the arsenic consumed was estimated to have been in compound form, primarily arsenic trioxide. The largest end use for arsenic trioxide was in the production of wood preservatives. The three principal producers of arsenical wood preservatives were Hickson Corp., Smyrna, GA; Chemical Specialties Inc., Harrisburg, NC; and Osmose Wood Preserving, Inc., Buffalo, NY. Osmose also produces arsenic acid that is used by the glass industry as a fining agent to disperse air bubbles. Arsenic also was used in some herbicides for weed control.

Arsenic metal was used as an additive to improve corrosion resistance and tensile strength in copper alloys and as a minor additive (0.01% to 0.5%) to increase the strength of the posts and grids in some lead-acid storage batteries. An estimated 40 t of high-purity arsenic metal (99.9999%-pure or higher) was used in the manufacture of gallium arsenide, a semiconductor used in various electronic devices including wireless phones and high-speed computers.

Arsenic in the 20th Century

In 1901, the United States began production of arsenic trioxide, with an output of approximately 270 metric tons. Previously, the U.S. was import dependent, relying on shipments from Canada and Europe. U.S. imports of arsenic metal, arsenic trioxide, and arsenic sulfides in 1901 totaled 3,170 tons. Arsenic was used primarily as a herbicide, insecticide, and pesticide. During the century that followed, U.S. arsenic production and use changed significantly. For a number of years, the United States was the world's largest arsenic producer. Because of its toxic nature, however, various rules and regulations were enacted, especially in the 1970s, to eliminate or curtail human exposure to arsenic. Consequently, U.S. production of arsenic declined significantly, from a high of 32,700 tons in 1944 to 2,200 tons in 1985, when the sole domestic refiner ceased production.

By the end of the century, the United States no longer produced arsenic and was import dependent. About 20,000 to 30,000 tons per year of arsenic was imported in the late 1990s, mostly in the form of arsenic compounds. During 2000, China was the largest supplier of arsenic to the United States, accounting for most imports of arsenic trioxide. Nearly all of the arsenic consumed domestically was used as a preservative in the production of pressured-treated wood.

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World Review

Arsenic trioxide was recovered from the smelting or roasting of nonferrous metal ores or concentrates in at least 16 countries in 2000. High-arsenic smelter or roaster dusts and residues that usually are not processed to commercial-grade trioxide were recovered in several other countries as well as at plants in countries producing commercial-grade material. Much of this material was stockpiled and could be available for future processing. Most countries did not report their arsenic production, and world production values had a high degree of uncertainty. China apparently remained the world's largest producer in 2000.

Commercial-grade (99%-pure) arsenic metal, produced through the reduction of arsenic trioxide, accounted for most world arsenic metal output. China accounted for nearly all the world's production of commercial-grade arsenic metal.

Worldwide, approximately 10 companies produced high-purity arsenic metal for use in the semiconductor industry.

Outlook

Despite environmental regulations that led to global disruption of production during the last decades of the 20th century, new sources of supply have emerged to fill the void. Given the abundance of arsenic in various waste streams, including nonferrous metal processing, world supplies of arsenic trioxide are expected to remain adequate to meet projected needs.

Because most arsenic is consumed as a compound in the production of arsenical wood preservatives used in home construction and renovation, arsenic demand is expected to correlate with changes in this market. In the short term, prohibitions on the use of arsenical wood preservative in certain applications is not expected to have any significant impact on demand. However, these prohibitions combined with the greater acceptance of alternative preservatives may reduce long-term demand.

Continued growth in the use of maintenance-free automotive batteries that require little or no arsenic will lower the demand for arsenic metal in this application; this decline, however, is likely to be offset somewhat by the consumption of arsenic to manufacture semiconductors.

References Cited

Focazio, Michael, Welch, A.H., Watkins, S.A., Helsel, D.R., and Horn, M.A., 2000, A retrospective analysis on the occurrence of arsenic in ground-water resources of the United States and limitations in drinking-water-supply characterizations: U.S. Geological Survey Water-Resources Investigations Report 99-4279, 22 p.

Goldhaber, Martin, Bigelow, R.C., Hatch, J.R., and Pashin, J.C., 2000, Distribution of a suite of elements including arsenic and mercury in Alabama coal: U.S. Geological Survey Miscellaneous Field Studies Map MF-2333, 1 sheet, various scales.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Arsenic. Ch. in Mineral Commodity Summaries, annual.
Arsenic. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Gallium. Ch. in Minerals Yearbook, annual.

Other

Arsenic. Roskill Information Services Ltd., 8th ed., 1992.
Gallium and Gallium Arsenide—Supply, Technology, and Uses. U.S. Bureau of Mines Information Circular 9208, 1988.
The Materials Flow of Arsenic in the United States. U.S. Bureau of Mines Information Circular 9382, 1994.
Wood Preserving Industry Production Statistical Report, 1996. American Wood Preserving Institute, 1998.

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TABLE 1
ARSENIC SUPPLY-DEMAND RELATIONSHIPS 1/

(Metric tons, arsenic content)

	1996	1997	1998	1999	2000
U.S. supply:					
Imports, metal	252	909	997	1,300	830
Imports, compounds	21,200	22,800	29,300	22,100	23,600
Total	21,400	23,700	30,300	23,400	24,500
Distribution of U.S. supply:					
Exports 2/	36	61	177	1,350	41
Apparent demand	21,400	23,700	30,100	22,000	24,400
Estimated U.S. demand pattern:					
Agricultural chemicals	950	1,400	1,500	1,100	1,000
Glass	700	700	700	700	700
Wood preservatives	19,200	20,000	27,000	19,000	21,000
Nonferrous alloys and electronics	250	900	1,000	1,300	800
Other	300	300	300	300	300
Total	21,400	23,700	30,100	22,000	24,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Metal only.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ARSENICALS 1/

	1999		2000	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	724	$429	576	$356
Bolivia	280	159	212	118
Canada	--	--	1	2
Chile	8,870	3,340	9,110	3,620
China	15,500	8,380	15,400	7,800
France	1,410	862	1,340	871
Germany	3	34	4	15
Hong Kong	70	42	406	232
Mexico	1,680	1,090	1,900	1,330
Morocco	148	90	2,180	1,150
Vietnam	437	251	--	--
Total	29,100	14,700	31,100	15,500
Arsenic acid, France	4	24	--	--
Arsenic metal:				
China	1,240	1,600	612	694
Germany	16	3,210	21	3,410
Hong Kong	--	--	41	36
Japan	45	3,580	157	5,660
United Kingdom	(2/)	7	(2/)	2
Total	1,300	8,390	830	9,800

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 3
ARSENIC TRIOXIDE: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/

(Metric tons)

Country 4/	1996	1997	1998	1999	2000 e/
Belgium e/	2,000	2,000	1,500	1,500	1,500
Bolivia	255	282	284	437 r/	280
Canada e/	250	250	250	250	250
Chile	8,000	8,350	8,400	8,000 e/	8,200
China e/	15,000	15,000	15,500	16,000	16,000
France e/	3,000	2,500	2,000	1,000	1,000
Georgia e/	400	400	400	400	400
Germany e/	250	250	200	200	200
Ghana 5/	5,443	4,577	5,000	7,000 r/ e/	3,000
Iran e/	500	492 r/	500	500	500
Japan e/	40	40	40	40	40
Kazakhstan e/	1,500	1,500	1,500	1,500	1,500
Mexico	2,942	2,999	2,573	2,419 r/	2,400
Namibia 6/	1,559	1,297	175	--	--
Peru 7/	111	103	122	120 e/	120
Portugal e/	100	50	50	50	50
Russia e/	1,500	1,500	1,500	1,500	1,500
Total	42,900	41,600	40,000	40,900 r/	36,900

e/ Estimated. r/ Revised. -- Zero.

1/ Including calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.

2/ World totals and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

3/ Table includes data available through March 30, 2001.

4/ Austria, Hungary, the Republic of Korea, South Africa, Spain, the United Kingdom, former Yugoslavia, and Zimbabwe have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make estimates of output levels, if any.

5/ Production ceased in mid-2000. Ashanti Goldfields Ltd. roaster closed.

6/ Output of Tsumeb Corp. Ltd. only; the mine closed in 1996 and the smelter in April 1998.

7/ Output of Empress Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.

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ASBESTOS

By Robert L. Virta

Domestic survey data and tables were prepared by Shantae F. Hawkins, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Asbestos is a generic name for six fibrous minerals that have been used in commercial products. The six types of asbestos are chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. Several properties that make asbestos so versatile and cost effective are high tensile strength, chemical and thermal stability, high flexibility, low electrical conductivity, and large surface area. Nearly all of the asbestos produced worldwide is chrysotile.

Legislation and Government Programs

The Occupational Safety and Health Administration (OSHA) solicited public comments on its information-collection requirements under its asbestos in general, shipyards, and construction standards. At issue are the quality of the information, ways to minimize the burden on employers, and whether or not the information collection is necessary and the burden has been correctly estimated (U.S. Department of Labor, 2000a, b, c).

The Environmental Protection Agency (EPA) increased coverage of State and local government employees under its asbestos worker protection rule (WPR) by incorporating OSHA's asbestos standards into the WPR. State and local government employees performing construction work, custodial work, and automotive brake and clutch repair work now are covered to the same extent as private sector workers. The WPR is cross-referenced to the OSHA asbestos standards for construction and for general industry so future amendments to the OSHA rules will also amend the WPR. Also, EPA's asbestos-in-schools rule was amended so that employees of local public education agencies who perform operations, maintenance, and repair activities under the asbestos-in-schools rule now are covered under the WPR (U.S. Environmental Protection Agency, 2000).

The EPA continued to test for the presence of asbestos in and around a vermiculite mine in Libby, MT. The agency has sampled indoor air, soil, dust, and insulation for asbestos. It began conducting more extensive sampling in March 2001. The agency also has completed some preliminary health studies on local residents and former workers at the vermiculite operation (U.S. Environmental Protection Agency, February 22, 2001, Libby Community Advisory Group, accessed March 8, 2001, at URL http://www.epa.gov/region8/superfund/libby/cag2-22.html#drl).

Following the controversy over Libby, MT, the Mine Safety and Health Administration inspected Virginia Vermiculite Co.'s mine in Virginia to determine asbestos levels. Air monitoring was conducted, and asbestos was not detected using the required sampling and analysis protocol. There remains a controversy, however, over how the samples were analyzed and

Asbestos in the 20th Century

Prior to 1900, U.S. demand for asbestos was less than 10,000 metric tons per year because technological development had not yet created large markets for asbestos. In 1900, though, U.S. demand had reached 20,000 tons and was growing. The expanding automotive and building industries provided ready markets for asbestos in the early 1900s. Demand for such items as asbestos brake shoes and clutches, asbestos-cement products, asbestos flooring, asbestos packings and gaskets, and asbestos thermal and electrical insulation grew rapidly. By 1950, 660,000 tons of asbestos was used by domestic manufacturers, making the United States the largest user of asbestos in the world. With the expansion of the economy after World War II, demand for asbestos continued to increase, reaching 801,000 tons by 1973.

In 2000, U.S. demand for asbestos returned to levels achieved in the late 1800s, about 14,600 tons or only 1.8% of the 1973 demand. The collapse in U.S. markets for asbestos began in the early 1970s in response to health and liability issues. First, it became well established that excess exposures to asbestos could result in the development of asbestosis and lung cancer, prompting the filing of large class-action suits against mining companies and manufacturers of asbestos products on behalf of workers suffering from these diseases. Second, strong public opposition to the use of asbestos began to affect sales of asbestos products and influence legislation dealing with asbestos. As a result, U.S. demand for asbestos plummeted as manufacturers either ceased production of asbestos-containing products, began using asbestos substitutes, or replaced asbestos-containing products with ones that did not contain asbestos. Asbestos markets, which took more than 100 years to peak, completely reversed themselves in less than 25 years. The decline in demand resulted in major shifts in the use of asbestos. The major uses for asbestos in 2000 were roofing products, gaskets, and frictions products, with 62%, 21%, and 12% of the market, respectively compared with 1973 when major markets were asbestos-cement pipe (24%), flooring (22%), roofing (9%), friction products (brakes and clutches) (8%), and packing and gaskets (3%).

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whether the current methodology and exposure levels adequately protect the workers from exposure to asbestos (Industrial Minerals, 2000d; North American Minerals News, 2000b).

A variety of asbestos-containing products, such as brakes, gaskets, and asphalt roofing products, are used by the military on vehicles, ships, and missiles and in construction. Strategic-grade asbestos is not required in the manufacture of these products, and classified applications in which strategic-grade asbestos is used are believed to be minimal. The U.S. Department of Defense disposed of alls of the strategic- and nonstrategic-grade amosite, chrysotile, and crocidolite from the national defense stockpile in 2000.

Production

KCAC Inc. in San Benito County, CA, was the only company mining asbestos in the United States in 2000. The company mined a highly sheared serpentinite containing matted, short-fiber chrysotile and unfractured serpentinite (also called a mass-fiber deposit). Domestic production (sales) decreased by 27% to 5,260 metric tons (t) in 2000 from 7,190 t in 1999 (table 1). Domestic production data for asbestos were collected by means of a voluntary survey of the one domestic mining operation, representing 100% of the sales data shown in table 1.

Consumption

U.S. consumption of asbestos was 14,600 t, 8% less than that of 1999. The three leading domestic markets were roofing products, gaskets, and friction products, with 62%, 22%, and 12%, respectively, of the asbestos market. Essentially all of the asbestos used in manufacturing in the United States was chrysotile; 94% was grade 7, followed by grades 6, 5, 4, and 3, in decreasing order of consumption. A few tons of crocidolite may still be used for specialized applications, but this cannot be verified (table 2).

Prices

The average unit value of domestically produced asbestos increased from that of 1999. The average U.S. customs unit value for imported crude chrysotile decreased by 14% to $118 per metric ton in 2000. The average unit value for imports of spinning-grade chrysotile was $1,470 per ton, a 13% increase from that of 1999. Low-tonnage, high-value imports from South Africa and Zimbabwe caused the increase in the unit value. The unit value of the other grades of chrysotile decreased by 2% to $163 per ton in 2000. Imports of chrysotile from South Africa and Zimbabwe had the highest unit values. The average unit value of chrysotile imported from South Africa was $1,930 per ton and from Zimbabwe was $2,050 per ton (table 6).

The U.S. customs unit value for the crude and spinning grades of chrysotile fiber from Canada were $118 and $184 per ton, respectively (tables 3 and 6). Imports of "Other, chrysotile" from Canada were valued at $159 per ton (tables 3 and 6). Crocidolite imports reported by the U.S. Census Bureau were valued at $108 per ton (see discussion under Foreign Trade concerning crocidolite imports).

Prices ranged from $135 to $1,168 per ton for Canadian chrysotile and $200 to $440 per ton for South African chrysotile, depending on the grade (Industrial Minerals, 2000b). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade

The export free alongside ship (f.a.s.) value of asbestos fibers and products containing asbestos or asbestos substitutes increased by 21% to $296 million in 2000 from $245 million in 1999. Exports of brake linings, pads, and mounted brake linings accounted for most of this increase.

Mexico and Japan were the leading importers of asbestos fiber from the United States. Canada was the leading importer of U.S. products manufactured using asbestos or asbestos substitutes, followed by Germany, Mexico, Japan, and the United Kingdom (table 4). These five countries accounted for 81% of the value of asbestos products exported from the United States.

Exports and reexports of brake linings, disk pads, and mounted brake linings accounted for 87% of the value of all manufactured asbestos products (table 5). Products in these categories composed 94% of the value of goods manufactured using asbestos and asbestos substitutes that were exported to Canada, 95% of that exported to Mexico, 99% of that exported to Germany, and 91% of that exported to Japan.

In 2000, approximately 18,800 t of asbestos was exported, according to the U.S. Census Bureau. The exports included asbestos crudes, fiber, sand, refuse, and stucco. Exports of domestic origin were estimated to be approximately 5,000 t. Reexports of Canadian fiber accounted for the bulk of the remaining exports (mainly through New York), although some manufactured products and nonasbestos mineral exports may have been included in the 18,800 t.

In 2000, Canada supplied 99% of the asbestos imported by the United States. Imports also were reported from South Africa (53 t) and Zimbabwe (54 t) (table 6). The U.S. Census Bureau reported 67 t of crocidolite imported in 2000. Based on its unit value and country of origin (Canada), it is likely that the asbestos was chrysotile rather than crocidolite. Chrysotile composed more than 99% of the asbestos imported into the United States in 2000.

The United States also imported $166 million of asbestos products. This includes approximately 51,500 t valued at $26.3 million of asbestos- and cellulose-fiber cement products (A/C), including panels, pipe, and tile. The bulk of the A/C products was imported in the form of flat sheets and panels (92%), followed by corrugated sheet (3%), pipe (1%), and other (4%).

World Review

World production of asbestos was estimated to be 1.9 million metric tons. Russia continued to be the leading producer of asbestos, followed by Canada, China, Brazil, Kazakhstan, and

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Zimbabwe. These countries accounted for 93% of the world production (table 7).

The controversy over the use of asbestos continued to be the focus of attention worldwide. Bans have already been enacted in many European countries. In 2000, Saõ Paulo became another of several Brazilian cities that enacted an asbestos ban. Chile began drafting legislation to ban the use of asbestos, with certain exceptions. This was subsequently enacted in 2001 (International Ban Initiative Secretariat, February 15, 2001, Chile bans asbestos, accessed March 27, 2001, at URL http://www.btinternet.com/~ibas/Frames/F_LKA_Chile_Ban.htm).

Canada.—Production of chrysotile from the Cassiar Magnesium Inc. operation in British Columbia, which began in January 2000, has been suspended following a fire in the mill facility. Damage is being evaluated but a date for resuming operations has not been set. The company marketed its chrysotile internationally with customers in Dubai, India, Indonesia, Iran, Japan, Sri Lanka, and Thailand. Plans are in place for the installation of a wet-processing plant that would bring annual capacity to 50,000 metric tons per year (t/yr). Cassiar Magnesium is proceeding with its development of a facility to process serpentine tailings for magnesium. Metal production is not anticipated until 2003 or 2004 (North American Minerals News, 2000a; Canada NewsWire, December 27, 2000, Cassiar mill damaged by fire, accessed December 30, 2000, at URL http://www.newswire.ca/releases/December2000/27/c6332.html).

France.—The World Trade Organization (WTO) upheld France's decision to ban asbestos use. The ruling was based on WTO guidelines for health protection, which superseded its free trade rules. The Canadian Government announced that it will appeal the decision on grounds that the ban may not comply with trade agreements (Industrial Minerals, 2000a; Morrison and Williams, 2000).

Russia.—Uralasbest, the leading Russian asbestos producer, announced plans for installing a 50,000 t/yr magnesium plant at its operation in Sverdlovsk. The plant will cost $300 million and will process serpentine tailings from the asbestos operation. Uralasbest will use the technology developed by Solikamsk Magnesium Plant, a leading Russian magnesium producer. Solikamsk, which has been producing magnesium from carnallite, announced plans to use asbestos tailing from Uralasbest's Bazhenovskoye asbestos mine (Mining & Metals Report, 2000).

Uralasbest sought an exclusion from new import custom duties on asbestos from the Russian Parliament. The new rate will be 30% higher than previously. Uralasbest, which payed its wages in arrears and reduced its tax indebtedness in 1999, also faces opposition to the use of asbestos and erratic production resulting from power outages (Industrial Minerals, 2000c).

Outlook

Domestic markets for asbestos probably will remain unchanged or decline only slightly over the next few years. Friction products, gaskets, and roofing products will continue to be the only significant domestic markets of asbestos for the foreseeable future in the United States. The slow recovery of the Southeast Asian economies and continued efforts to ban asbestos use worldwide are likely to result in a slight downturn in sales worldwide.

References Cited

Industrial Minerals, 2000a, France's asbestos ban hits Canada: Industrial Minerals, no. 396, September, p. 90.

———2000b, Prices: Industrial Minerals, no. 399, December, p. 74.

———2000c, Uralasbest asks for freeze on asbestos export duty: Industrial Minerals, no. 393, June, p. 25.

———2000d, Virginia Vermiculite in the hot seat: Industrial Minerals, no. 398, November, p. 19-20.

Mining & Metals Report, 2000, Uralasbest to add magnesium plant: Mining & Metals Report, v. 9, no. 15, April 7-13, p. 11.

Morrison, Scott, and Williams, Frances, 2000, Canada to appeal against WTO ruling on asbestos: Financial Times, September 19, p. 5.

North American Minerals News, 2000a, Cassiar changes name to reflect mag-metal business: North American Minerals News, no. 61, June, p. 6.

———2000b, Virginia Vermiculite anger over MSHA scrutiny: North American Minerals News, no. 67, December, p. 3.

U.S. Department of Labor, 2000a, Asbestos in construction standard—Extension of the Office of Management and Budget's approval of information-collection (paperwork) requirements: Federal Register, v. 65, no. 211, October 31, p. 65010-65011.

———2000b, Asbestos in general industry standard—Extension of the Office of Management and Budget's approval of information-collection (paperwork) requirements: Federal Register, v. 65, no. 211, October 31, p. 65008-65009.

———2000c, Asbestos in shipyards standard—Extension of the Office of Management and Budget's approval of information-collection (paperwork) requirements: Federal Register, v. 65, no. 211, October 31, p. 65009-65010.

U.S. Environmental Protection Agency, 2000, Asbestos worker protection: Federal Register, v. 65, no. 221, November 15, p. 69209-69217.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Asbestos. Ch. in Mineral Commodity Summaries, annual.

Asbestos. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Asbestos. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Asbestos Cement Product Producers Association.

Asbestos Information Association/North America.

Mining Engineering.

The Asbestos Institute.

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TABLE 1
SALIENT ASBESTOS STATISTICS 1/

(Metric tons, unless otherwise specified)

		1996	1997	1998	1999	2000
United States:						
Production (sales)		9,550	6,890	5,760	7,190	5,260
Exports and reexports: 2/						
Unmanufactured, value	thousands	$5,310	$5,690	$6,410	$7,960	$7,220
Asbestos products, value	do.	$163,000	$197,000	$194,000	$237,000	$288,000
Imports for consumption, unmanufactured:						
Quantity		21,600	20,900	15,800	15,800	14,600
Value 3/	thousands	$4,880	$4,660	$3,240	$3,150	$2,510
Consumption, apparent 4/		21,700	21,000	15,800	15,800	14,600
World production		2,100,000	2,110,000	1,810,000 r/	1,830,000 r/	1,900,000

r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ F.a.s. value; includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.

3/ U.S. Customs declared value.

4/ Production plus imports minus producer exports of asbestos fiber plus adjustments in Government and industry stocks.

TABLE 2
U.S. ASBESTOS CONSUMPTION BY END USE, GRADE, AND TYPE 1/ 2/

(Metric tons)

	Chrysotile							
End use	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Total	Crocidolite 3/	Total asbestos
1999	59	73	649	205	14,800	15,800	--	15,800
2000:								
Coatings and compounds	--	--	--	--	92	92	--	92
Friction products	--	82	58	25	1,520	1,680	--	1,680
Insulation, thermal	--	--	--	--	179	179	--	179
Gaskets	--	--	20	457	2,610	3,090	--	3,090
Plastics	--	1	--	--	--	1	--	1
Roofing products	--	--	--	--	9,070	9,070	--	9,070
Other	7	84	252	--	179	522	--	522
Total	7	167	330	482	13,700	14,600	--	14,600

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Estimated distribution based upon data provided by the Asbestos Institute, Montreal, Canada, and the U.S. Geological Survey asbestos producer survey.

3/ May include imports of chrysotile. Estimated consumption of crocidolite was less than 5 tons.

TABLE 3
CUSTOMS UNIT VALUE OF IMPORTED ASBESTOS

(Dollars per metric ton)

	1999	2000
Canada:		
Chrysotile:		
Crude	149	118
Spinning	108 r/	184
Other	149 r/	159
South Africa: Crocidolite 1/	--	108

r/ Revised. -- Zero.

1/ May include imports of chrysotile.

Source: U.S. Census Bureau.

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TABLE 4
U.S. EXPORTS AND REEXPORTS OF ASBESTOS FIBERS AND PRODUCTS 1/ 2/

(Thousand dollars)

Country	1999			2000		
	Unmanufactured fiber 3/	Manufactured products 4/	Total	Unmanufactured fiber 3/	Manufactured products 4/	Total
Australia	--	1,960	2,020	56	1,180	1,240
Brazil	55	465	520	100	2,510	2,610
Canada	4	117,000	117,000	4	112,000	112,000
Germany	24	11,600	11,700	15	71,600	71,600
Japan	2,280	6,240	8,510	1,860	12,300	14,100
Korea, Republic of	127	1,520	1,650	302	1,100	1,400
Kuwait	3	398	401	--	313	313
Mexico	5,070	60,100	65,200	4,650	32,900	37,500
Saudi Arabia	--	1,680	1,680	--	2,020	2,020
Thailand	108	12	119	4	8	12
Turkey	--	7	7	--	51	51
United Kingdom	4	4,810	4,820	3	5,780	5,780
Venezuela	--	2,770	2,770	--	2,660	2,660
Other	222	29,100	29,300	234	44,300	44,500
Total	7,960	237,000	246,000	7,220	288,000	296,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ F.a.s. value.
3/ Includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.
4/ Also includes products manufactured using asbestos substitutes.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS AND REEXPORTS OF ASBESTOS AND ASBESTOS PRODUCTS 1/

	1999		2000	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Unmanufactured, asbestos 3/	21,700	$7,960	18,800	$7,220
Manufactured:				
Asbestos fibers	NA	2,310	NA	2,820
Brake linings and disk brake pads 4/	NA	192,000	NA	250,000
Clutch facings and linings 5/	NA	22,200	NA	9,540
Clothing, cord, fabric, yarn	NA	1,270	NA	2,300
Gaskets, packing and seals	NA	2,650	NA	2,470
Panel, sheet, tile, tube 6/	NA	9,790	NA	14,000
Paper and millboard	NA	1,410	NA	1,150
Other articles 7/	NA	5,800	NA	6,320
Total	NA	237,000	NA	288,000

NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ F.a.s. value.
3/ Includes crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.
4/ Includes asbestos and cellulose fiber brakes and similar materials.
5/ Includes clutches and other friction materials, excluding brakes and brake pads.
6/ Includes asbestos cement and cellulose fiber cement products.
7/ Includes asbestos and cellulose fiber products.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF ASBESTOS FIBERS, BY TYPE, ORIGIN, AND VALUE 1/

Type	Canada		South Africa		Other		Total	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
1999:								
Chrysotile:								
Crude	2,350	$350	--	--	--	--	2,350	$350
Spinning fibers	65	7	284	$421	42	$82	391	510
All other	11,200	1,670	9	32	80	156	11,200	1,860
Other (unspecified asbestos type)	769	303	--	--	1,060	130	1,820	434
Total	14,300	2,330	293	453	1,180	368	15,800	3,150
2000:								
Chrysotile:								
Crude	3,350	394	--	--	--	--	3,350	394
Spinning fibers	31	6	53	102	38	71	122	179
All other	10,500	1,670	--	--	16	40	10,500	1,710
Crocidolite (blue) 3/	67	7	--	--	--	--	67	7
Other (unspecified asbestos type)	581	217	--	--	--	--	581	217
Total	14,500	2,300	53	102	54	111	14,600	2,510

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ U.S. customs declared value.

3/ Reported by the U.S. Census Bureau. Its source suggests the imports labeled as crocidolite probably were a combination of chrysotile imports and transshipments of crocidolite through Canada.

Source: U.S. Census Bureau.

TABLE 7
ASBESTOS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Argentina e/	446 4/	400	380	350	350
Brazil e/	170,000	170,000	170,000	170,000	170,000
Bulgaria	400	300	300 e/	350 e/	350
Canada	506,000	455,000	309,000	337,366	340,000
China e/	293,000	288,000	314,000	247,000 r/	260,000
Egypt e/	1,836 4/	2,000	2,000	2,000	2,000
Greece e/	80,213 4/	80,000	70,000	60,000	50,000
India	23,215	25,051	18,751	20,000 e/	21,000
Iran e/	4,500	4,300 r/	2,258 r/ 4/	2,000 r/	2,000
Japan e/	18,000	18,000	18,000	18,000	18,000
Kazakhstan e/	128,700 4/	125,000	125,000	125,000	125,000
Russia e/	615,000	710,000	600,000	675,000 r/ 4/	750,000
Serbia and Montenegro	509	360	633 r/	361 r/	550
South Africa	57,120	49,986	27,195	18,700 r/ e/	18,909 4/
Swaziland	26,014	25,888	27,693	28,000 e/	25,000
United States (sold or used by producers)	9,550	6,890	5,760	7,190	5,260 4/
Zimbabwe	165,494	144,959	123,295	115,000 r/	110,000
Total	2,100,000	2,110,000	1,810,000 r/	1,830,000 r/	1,900,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Marketable fiber production. Table includes data available through April 6, 2001.

3/ In addition to the countries listed, Afghanistan, North Korea, Romania, and Slovakia also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

4/ Reported figure.

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BARITE

By James P. Searls

Domestic survey data and tables were prepared by Jeff Milanovich, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Barite, a name that was derived from the Greek word "barys" (heavy), is the mineralogical name for barium sulfate. In commerce, the mineral is sometimes referred to as "barytes." As used in this report, the term "primary barite" refers to the first marketable product, which includes crude barite (run of mine) and the products of simple beneficiation methods, such as washing, jigging, heavy media separation, tabling, flotation, and magnetic separation. Most crude barite requires some upgrading to minimum purity or density. Barite that is used as an aggregate in a heavy cement is crushed and screened to a uniform size. Most barite is ground to a small uniform size before it is used as a filler or extender, an addition to industrial products, or a weighting agent in petroleum well-drilling mud [American Petroleum Institute (API) or Oil Companies' Materials Association (OCMA)] specification barite. Barite used for drilling petroleum wells can be blue, black, buff, brown, or gray depending on the ore body. It must be finely ground so that at least 97% of the material, by weight, can pass through a 200-mesh (75-micrometer) (Tyler) screen, and no more than 30%, by weight, can be less than 6 micrometers in effective diameter, which is measured using sedimentation techniques. The ground barite also must be dense enough that its specific gravity is 4.2 or greater, soft enough to not damage the bearings of a tricone drill bit, and both chemically inert and containing no more than 250 milligrams per kilogram of soluble alkaline salts (American Petroleum Institute, 1993, p. 6-11). A small percentage of iron oxide is allowable. An additional feature of barite is noninterference with magnetic measurements taken in the borehole, either during logging while drilling or in separate drill-hole logging. In offshore drilling, the U.S. Environmental Protection Agency limits the content of mercury to 1 milligram per kilogram of barite and that of cadmium to 3 milligrams per kilogram of barite (U.S. Environmental Protection Agency, 1997). Although barite contains a heavy metal (barium), it is not a toxic chemical under section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 because it is very insoluble.

Production

Domestic sales data for barite were derived from voluntary responses to a survey of U.S. operations and follow-up telephone calls by the U.S. Geological Survey. Barite production for 2000 was 392,000 metric tons (t), about 9% below that of 1999. Of the known 31 operations, 16 responded to survey forms, and 15 responded by telephone. Nine mines were included in the survey; six were producing, and three were idle. Of the producing mines, three were in Nevada, two were in Georgia, and one was in Tennessee; two idle mines were in Nevada, and one was in Missouri. There were 24 mills/grinding plants operating for the report year, and an additional plant was being refurbished. Three plants were in Nevada, all associated with mines (one mine was idle). Two grinding plants in Georgia were associated with mines, and two plants in Illinois

Barite in the 20th Century

At the beginning of the 20th century, barite was a mineral of minor importance to the United States. Its primary use was to extend lead oxide in white paint. Barite also added the special qualities of hiding power and flatness. Because white lead sometimes turns black or yellow and barite does not, ground barite became a pigment on its own merit. Barite was also converted to other barium chemicals. Barium chloride was added to bricks before firing to stop efflorescence when exposed to weather. Barium chemicals were used for refining sugar, enameling iron, making oilcloths and paper collars, and in the manufacture of paper, artificial ivory, rubber, and lithopone. Barium carbonate or nitrate adds luster and brilliance to glass. Lithopone became a major paint ingredient in the 1920s; its use lasted into the 1950s, peaking at 150,000 metric tons per year of barite in both 1937 and 1947 entering the manufacture of lithopone. Later in the century, however, titanium dioxide replaced lead oxide, barite, and zinc oxide in the coating industry. Another barite use was patented in 1926 by the oil well drilling industry.

During the later part of the century, barite was used in the drilling mud of oil and gas wells, particularly for wells deeper than 2,000 meters, and petroleum-well-drilling demand for barite became the mineral's major end use during economic expansions after World War II and the subsequent increased use of oil and gas in the United States. The profitability of oil and gas production had a strong effect on the number of drill rigs, and the number of drill rigs had a strong effect on the consumption of barite. The United States was the leading petroleum well drilling country starting in 1970, reaching 4,530 drill rigs in December 1981, and was the largest consumer of barite. Record highs of about 2.6 million tons of barite produced and 4.3 million tons consumed in the United States were reported in 1981. Barite production and consumption declined since then to 400,000 tons produced, 2.1 million tons imported into the United States, and 6.2 million tons produced worldwide in 2000. Barite industrial end uses accounted for an estimated 78,000 tons per year in the United States.

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used imported crude barite. One grinding plant in California was associated with a mine in Nevada, and one grinding plant in Missouri used material from a stockpile from a nearby idle mine. Five of the six active mines had grinding plants. There were 15 facilities on the Gulf of Mexico that produced API-grade barite in 2000; an additional plant was undergoing renovation in Morgan City, LA. These grinding plants received relatively low priced crude barite from China and India for grinding to petroleum-well-drilling specifications and small amounts for filler and extender markets. In Texas, there were two plants in Brownsville, three in Corpus Christi, one in Galveston, and two in Houston. In Louisiana, there was a grinding plant in Houma, two near Lake Charles, one in New Iberia, one near Morgan City, and two near New Orleans. At yearend, one plant in New Orleans was relocated to Morgan City. Baker Chemical, Inc., closed and sold its two plants.

The quantity of primary barite sold or used by producers fell by about 10% from that of 1999, and weighted average prices declined by about 5%. Less than 4% of barite sales from domestic producers were for industrial end uses. The remaining sales were for petroleum-well-drilling API-specification markets. None of the Nevada-mined ore was sent to the coast of the Gulf of Mexico for grinding. High quality lump barite entered the country for several filler and extender grinding plants in the Midwest United States.

Halliburton Co. owned the Baroid Drilling Fluids Division. A joint venture between Smith International Inc. and Schlumberger Ltd. owns M-I LLC, which owns M-I Drilling Fluids. The third major U.S. barite company was Baker Hughes Inteq, a division of Baker Hughes, Inc. These three companies mined barite in Nevada and in countries with collocated beneficiation plants (mills) and grinding plants, along with the above-mentioned grinding plants in Louisiana and Texas. Excaliber Minerals, Inc., a division of Newpark Resources Inc., has become significant in the imported barite grinding industry in Louisiana and Texas.

These four companies on the Gulf of Mexico received imported barite that was transported by ship to Louisiana and Texas shores. These Gulf of Mexico locations are closer to the large offshore drilling rigs in the Gulf of Mexico and the clusters of onshore areas of exploration and significant discoveries (plays) in the Petroleum Administration for Defense District 3 (where searching for gas and oil is most profitable).

The outputs of crushers and grinders in Louisiana increased by more than 34%, while the outputs of crushers and grinders in Texas increased by nearly 157% (table 2). Industrial end-use sales by crushers and grinders of domestic production and imported barite in 2000 was essentially unchanged (table 3).

These four producers and other smaller companies import and grind or crush barite for drilling mud. Two smaller companies mine and beneficiate barite for the filler and the extender and chemical industries in Georgia, and a small mine and a mill operate in Nevada and California for the same end use. Two companies import or purchase domestic barite for grinding in Illinois for the Midwest filler and extender and chemical industry markets. The Quincy, IL, grinding plant owner changed its name to Elementis Pigments Inc. from Harcros Pigment Inc.

Trade

Domestic exports were about 36,000 t, mostly to Canada (table 4). Imports of Chinese barite increased by nearly 200% above that of 1999 to equal about 93% of total barite imports of 2.1 million metric tons (Mt). Imports from India declined by more than 25% from those of 1999 to 101,000 t (table 5).

Consumption

Barite apparent consumption increased by about 91% compared with that of 1999 to less than 2.5 Mt. Ground barite sales climbed by about 53% to 2.1 Mt. Barite imports during 2000 were up by 140% to 2.1 Mt from 870,000 t.

Since 1975, about 90% of the consumption of barite has been used during the operation of drill rigs to explore for, discover, develop, and expand petroleum reserves. Often the demand for drill rigs to explore and develop petroleum reserves rises as the prices of oil and gas rise. For the oil-directed rigs, the average futures price of light sweet west Texas crude started the year at about $26.30 per barrel for the last day of December 1999; rose to about $32.10 per barrel, as reported for June 28; and declined to around $29.00 per barrel, as reported for December 15, 2000 (Oil & Gas Journal, 2000-2001). Oil-directed drill rigs in the United States increased to around 205 rigs between April through late August from about 130 rigs in late January and then rose to about 245 rigs in mid-December. For the year, this increase was a mild increase, where the oil-directed rigs rose from about 18% of total rigs to about 21% of total rigs in response to the oil price increase. For the gas-directed rigs, the futures price for natural gas was about $2.34 per million British thermal units on the last day of December 1999 and rose to $8.18 per million British thermal units in mid-December 2000 (Oil & Gas Journal, 2000-2001). Gas-directed rigs in the United States increased to 862 rigs in mid-December 2000 from 624 rigs on the last day of December 1999. The gas-directed rig count change was also mild and declined slightly to about 79% of total rigs from 82% in response to the gas price increase (Oil & Gas Journal, 2000-2001).

The reason for the increase in the number of oil-directed rigs seems to have been that drilling for oil, in contrast to 1998, was once again a profitable investment, as described by the Herold 34th annual replacement reserve cost analysis (Cacchione and Johnson, 2001). According to the Herold study, proven oil reserves "of the top 50 companies based upon size of U.S. proved reserves (among public companies that have filed SEC[1] disclosures by April 13, 2000)" increased by 9.4% [1.5 billion barrels (Gbbl)] from the beginning-of-the-year 15.9 Gbbl by extensions and discoveries (drilling) at a cost of about $5.17 per barrel of oil equivalent in 2000 (Cacchione and Johnson, 2001). This was a significant decrease from the $13.04 per barrel of oil equivalent for 1998 that drove down the use of drill rigs and barite in 1999. The oil companies also "increased reserves by 22.6% or 3.6 Gbbl by 'purchase of reserves'," which cost about $4.73 per barrel of oil equivalent. The top 50 oil companies probably increased drilling, and there was also an increase in drilling from the smaller independents who had money to search for more oil reserves having sold their proven reserves to the larger, integrated companies.

[1]Securities and Exchange Commission.

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According to the Herold study, proven gas reserves for their 50 biggest companies increased for the year 2000 to 102 trillion cubic feet from 86.8 trillion cubic feet (Cacchione and Johnson, 2001). There was a 13% increase, 11.3 trillion cubic feet, in reserves from 86.8 trillion cubic feet at the beginning of the year by extensions and discoveries (drilling) and 16.8% or 14.6 trillion cubic feet from 86.8 trillion cubic feet by purchase of reserves. Production was 10.0 trillion cubic feet with end-of-year proven gas reserves of 102 trillion cubic feet. "For the first time in 5 years extensions and developments outpaced gas production" (Cacchione and Johnson, 2001). There was also 1.1 trillion cubic feet of improved recovery and 1.4 trillion cubic feet of [reserve] revisions. The same analysis reported that finding and development costs (drilling), not broken down by oil and gas, fell to $5.17 per barrel of oil equivalent in 2000 from $5.31 per barrel of oil equivalent in 1999 and $13.04 per barrel of oil equivalent in 1998. Gas rigs continued to account for about 80% of the total rig count, staying between 74.6% and 82.6% for the year in the United States.

Drilling for oil and gas was more successful and continued to be rewarded by higher prices all through the year (Cacchione and Johnson, 2001). Results for individual companies varied widely, though. For example, BP Amoco, the biggest capital investor in the U.S. petroleum market for the year, spent $3.5 billion in finding and development. At its oil operations, BP Amoco produced 251 million barrels (Mbbl) of oil but revised its oil reserves downwards by 167 Mbbl for a total reserve reduction of 418 Mbbl for the year. At its gas operations, BP Amoco added 1.9 trillion cubic feet of natural gas reserves by extensions and discoveries, improved recovery, and reserve revisions, all products of drilling. BP Amoco also had a 0.4-trillion-cubic-foot final increase after gas reserve purchases of proven property, sales of property, and production of gas for the year. Not all companies had these results, but when summed, the top 50 petroleum companies achieved a 163% reserve replacement rate of oil production by drilling and a 138% reserve replacement rate of gas production by drilling.

Prices

The nominal average weighted sales price for primary barite from mines and associated beneficiation plants in the United States decreased slightly to about $25.10 per ton in 2000. Nominal average prices for crushed and ground barite decreased by 4% to $75.80 per ton compared with those of 1999. The weighted average prices of the production from "other" regions declined by about 11% while Louisiana and Texas prices were relatively unchanged.

According to Industrial Minerals (2000b), midyear international barite prices were as follows:

- API, lump, cost, insurance, and freight (c.i.f.) [U.S.] Gulf Coast, Chinese, $43 to $45 per ton; Indian, $45 to $48; Moroccan, $50 to $52.
- Unground, OCMA/API, bulk, specific gravity 4.2, free on board (f.o.b.) Morocco, $39 to $41 per ton.
- Ground, bagged, specific gravity 4.22, f.o.b. Morocco, $75 to $85 per ton.
- Ground, OCMA/API, big bags (1.5 tons) f.o.b. south Turkey, $68 to $70 per ton.
- Ground, OCMA, bulk, delivered Aberdeen [United Kingdom], $75.61 to $83.17[2] [£50 to £55] per ton; delivered Great Yarmouth [United Kingdom], $87.71 to $98.29 [£58 to £65] per ton.
- Micronized, off-white, minimum 99%, less than 20 micrometers, delivered United Kingdom, $211.71 to $226.83 [£140 to £150] per ton.
- Ground, white, paint-grade, 96% to 98% barium sulfate ($BaSO_4$), 350 mesh, 1 to 5 tons delivered United Kingdom, $294.88 to $332.68 [£195 to £220] per ton.

World Review

Since 1975, about 90% of consumed barite has been used with drill rigs to explore for, discover, develop, and expand petroleum reserves. Often the demand for drill rigs to explore and develop petroleum reserves rises as the prices of oil and gas rise. On the last day of December 1999, the futures price of west Texas light sweet crude was about $26.30 per barrel and Brent 38° crude was also about $26.30 per barrel (Oil & Gas Journal, 2000-2001). Oil prices peaked in November 2000, with the west Texas light sweet crude at about $35.25 per barrel and Brent 38° crude reaching about $33.40 per barrel.

According to the world drill rig reports, which do not cover most of the former and present centrally planned economies, the world drill rig count (with Canadian onshore drill rigs subtracted because their operations are strongly seasonal) rose to about 1,810 rigs at the end of 2000 from about 1,340 at the beginning of 2000 and about 1,100 rigs in April 1999 [Oil & Gas Journal, 2000-2001 (the third issue of each month)]. It would seem that barite consumption around the world rose for the year but there is no confirming data at this time. In ascending order of rig count, the following regions had active drill rigs:

Africa.—The African active drill-rig count rose to about 49 rigs in December from about 39 rigs in January, primarily with offshore drill rigs. Barite consumption probably increased in that region.

Europe.—European drill rigs rose to 96 total rigs in October from 65 total rigs in January, reaching a peak in October of a 31 rig increase, primarily with offshore rigs, which increased to about 57 rigs in October from about 33 rigs in January. Barite consumption probably increased in that region.

Asia and the Pacific.—The drill-rig count in Asia and the Pacific rose to about 155 in October from about 130 in January and settled to about 145 in December. The onshore drill-rig count increased by about 15 rigs while the offshore drill-rig count increased by about 10 rigs. Barite consumption probably increased in that region.

Middle East.—The Middle Eastern drill-rig count rose to about 165 in December from about 140 in January, with onshore rigs increasing by about 20 rigs, and offshore rigs, by about 5 rigs. Barite consumption probably increased in that region.

Latin America.—Latin American rigs increased to about 265 rigs in October from about 185 rigs in January. There were about 210 rigs onshore and 55 rigs offshore in October in reaction to petroleum prices; then the rig counts decreased by about 3 rigs onshore and 5 rigs offshore by December. Barite consumption probably increased in that region.

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[2]US$1.00=£0.6613

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Canada.—Canadian drill rig usage started the year at about 500 rigs in January, fell to a low of about 145 rigs in April, and recovered to about 410 active drill rigs in December. Canada went from a peak of 507 in February 1998 to a peak of 332 in February 1999 (and a low of 62 rigs in April), 544 in February 2000, and 562 in February 2001. Barite consumption probably increased in that region. Canada has a pattern of a high drill-rig count in the winter and a low drill-rig count in the spring in normal times. Canada is also an important gas supplier to the United States.

The major barite-producing countries, other than the United States, for which information was available were as follows:

China.—The producing mines are clustered in the south of China in Guangxi Province with 53% of production, which includes Nanning City; Hunan Province with 13% of production, which is north-by-northeast of Guangxi; and Guizhou Province with 13% of production, west of Hunan, and north-by-northwest of Guangxi (Newcaster, 2000). Guandong Province, with 9% of production, is east and up the southern coast of China and includes Hong Kong. Fujian Province, with 8% of production, is also on the coast to the northeast of Guandong Province and includes Fuzhou City. In 1997, a duopoly of "[t]he large two government owned" sellers forced up the price of barite in China, and in early 1998, when the demand for drilling started to falter due to low oil and gas prices in the United States and elsewhere, the duopoly kept mining and sending undergrade ore to the ports. In 1999, mining stopped, and port traders were caught with undergrade ore and no market (Newcaster, 2000). A new, more workable relationship with "[a]t least a dozen potential producers [who] are seeking direct supply agreements" was formed in 2000, when demand reawoke and barite grinders needed ore that met grade specifications.

Mexico.—"Chemical Products Corp. (CPC) of Cartersville, GA, owns the barytes producer Minas de Barita, which purchased Barita de Sonora S.A. at the end of 1997. Barita de Sonora is still not in production but CPC is carrying out feasibility studies to confirm the potential for chemical grade barytes production. No drilling grades will be produced" (Crossley, 2000, p. 70).

India.—A state entity controls the largest Indian barite source in Andhra Pradesh Province by annually leasing the mine source to the highest bidder (Newcaster, 2000). In fiscal year 1997-98, the successful bidder won with a bid that was too high for a market clearing price, and little barite left the country. In fiscal year 1998-99, India shipped barite to the United States with competitive prices. In fiscal year 1999-2000, Indian production was slowed down owing to government/trader/management disagreements and labor strikes.

Russia.—A new mine was opened in the Vorkuta district of the Komi Republic and was named the Khoilinsky deposit (Industrial Minerals, 2000a). The mine was reported to be near the eastern Siberian oil/natural-gas provinces with ores of more than 90% barite and enough reserves for 120,000-metric-ton-per-year production for more than 20 years. There was no mention of color or heavy metal occurrence or lack thereof.

Thailand.—Minerals traders in Thailand have started to deliver barite to the world market, reportedly using Thailand and Laotian material (Newcaster, 2000).

Outlook

In the United States, the gas industry looks more viable and profitable in the exploration and development departments and could be a market for barite consumption for many years. The amount of imported natural gas or substitute will indicate the health of this market in the future. The oil industry has returned to profitability with oil reserves that were found, as finding and developing costs per barrel of oil equivalent contracted down to normal levels. However, it may be that the barite-for-drilling-mud market will slowly move away from the United States over the long term as more petroleum fuel is imported into the United States and less is produced or as some other energy source replaces petroleum products in some end uses. The four barite suppliers will continue to support drilling activity as those centers of activity move to Africa, the Asia-Pacific region, and the former Soviet Union.

References Cited

American Petroleum Institute, 1993, Specification for drilling-fluid materials—Specification 13A: Washington, DC, American Petroleum Institute, May 1, 47 p.

Cacchione, N.D., and Johnson, Aaron, 2001, Herold 34th annual reserve replacement cost analysis: John S. Herold, Inc., April 30, 9 p.

Crossley, Penny, 2000, Far from just boring: Industrial Minerals, no. 395, August, p. 56-79.

Industrial Minerals, 2000a, Barytes mining begins at Khoilinsky: Industrial Minerals, no. 396, September, p. 29.

———2000b, Prices: Industrial Minerals, no. 394, July, p. 98.

Newscaster, John, 2000, The future of Asian drilling grade barytes: Industrial Minerals, no. 395, August, p. 49-55.

Oil & Gas Journal, 2000-2001, International rig count [monthly]: Oil & Gas Journal, various issues, various pages.

U.S. Environmental Protection Agency, 1997, Final effluent limitations guidelines and standards for the coastal subcategory of the oil and gas extraction point source category—Correction: Federal Register, v. 62, no. 8, January 13, p. 1681-1682.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Barite. Ch. in Mineral Commodity Summaries, annual.
Barite. Ch. in United States Minerals Yearbook, annual.
Barite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Barite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Barium Minerals. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Engineering and Mining Journal Annual Review.
Mining Engineering Annual Review.
Mining Journal Annual Review.

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TABLE 1
SALIENT BARITE STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Barite, primary:					
Sold or used by producers	662	692	476	434	392
Value	$14,700	$15,500	$11,400	$11,100	$9,840
Exports	31	22	15	22	36
Value	$3,190	$2,430	$2,310	$2,750	$4,180
Imports for consumption 3/	1,550	2,260	1,890	871	2,100
Value	$94,600	$136,000	$122,000	$59,000	$108,000
Consumption (apparent) 4/	2,180	2,930	2,350	1,280	2,460
Crushed and ground (sold or used by processors) 5/	1,870	2,180	1,890	1,370	2,100
Value	$141,000	$173,000	$146,000	$108,000	$159,000
World production	6,090	6,780 r/	6,460 r/	6,360 r/	6,200 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Barium chemicals data withheld to avoid disclosing company proprietary data.

3/ Includes crude and ground.

4/ Sold or used plus imports minus exports.

5/ Includes imports.

TABLE 2
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY STATE 1/ 2/

	1999			2000		
State	Number of plants	Quantity (thousand metric tons)	Value (thousands)	Number of plants	Quantity (thousand metric tons)	Value (thousands)
Louisiana	7	835	$63,900	7	1,120	$85,200
Texas	4	215	16,700	8	574	43,400
Other 3/	8	322	27,500	9	408	30,800
Total	19	1,370	108,000	24	2,100	159,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes imports.

3/ Includes California, Georgia, Illinois, Missouri (2000), and Nevada.

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TABLE 3
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	1999		2000	
	Quantity	Value	Quantity	Value
Barium chemicals, filler and/or extender, glass	78	13,500	77	18,000
Well drilling	1,290	94,600	2,030	141,000
Total	1,370	108,000	2,100	159,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes imports.

TABLE 4
U.S. EXPORTS OF NATURAL BARIUM SULFATE (BARITE), BY COUNTRY 1/

Country	1999		2000	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	131	$35	38	$10
Australia	--	--	17	9
Belgium	1	3	--	--
Canada	19,200	1,640	32,500	2,630
Chile	10	6	--	--
China	19	13	67	164
Colombia	17	8	2	9
Costa Rica	62	15	147	42
El Salvador	--	--	19	4
Guatemala	4	12	--	--
Hong Kong	--	--	16	5
India	--	--	7	15
Italy	--	--	260	58
Japan	61	109	234	61
Korea, Republic of	71	150	17	24
Mexico	2,220	721	2,890	959
Netherlands	--	--	4	20
Oman	5	18	11	47
Saudi Arabia	--	--	6	56
Singapore	1	3	--	--
South Africa	--	--	13	4
United Arab Emirates	9	21	--	--
Venezuela	--	--	82	63
Total	21,800	2,750	36,300	4,180

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BARITE, BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Barite, crude:				
Australia	57	$17	--	--
Canada	14,100	3,060	9,930	$2,080
China	654,000	32,600	1,950,000	84,000
Germany	2,700	205	3,340	158
India	136,000	5,990	101,000	5,950
Japan	91	7	--	--
Mexico	2,320	139	2,340	195
Thailand	26,500	1,410	--	--
United Kingdom	--	--	290	23
Total	836,000	43,500	2,070,000	92,400
Barite, ground:				
China	17,200	1,250	15,000	1,540
Mexico	--	--	1,190	120
Total	17,200	1,250	16,200	1,660
Barite, other sulfates of:				
Belgium	12	9	--	--
Canada	636	641	623	533
China	304	122	298	107
Germany	8,350	9,210	8,800	8,890
Italy	4,360	2,620	4,650	2,680
Japan	465	1,260	742	1,540
Mexico	3,280	371	--	--
Netherlands	117	46	147	96
Spain	--	--	40	49
Switzerland	--	--	20	28
Thailand	1	9	1	10
Turkey	13	23	5	8
United Kingdom	--	--	33	48
Total	17,500	14,300	15,400	14,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF BARIUM CHEMICALS 1/

Chemicals	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Barium chloride	1,990	$1,510	1,240	$752
Barium oxide, hydroxide, peroxide	4,310	4,460	5,290	4,770
Barium nitrate	3,940	3,320	4,930	4,540
Barium carbonate, precipitated	25,400	14,400	26,200	14,300
Other barium compounds	13,200	13,100	14,100	13,100

1/ Data are rounded to no more than three significant digits.
2/ C.i.f. value.

Source: U.S. Census Bureau.

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TABLE 7
BARITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Afghanistan e/ 4/	2,000	2,000	2,000	2,000	2,000
Algeria	31,348	39,140 r/	37,006 r/	50,150 r/	50,000
Argentina	14,038	13,121 r/	13,500 r/	4,365 r/	4,400
Australia e/	12,000	15,000	13,000	18,000	20,000
Belgium e/	30,000	30,000	40,000	30,000	30,000
Bulgaria e/ 5/	120,000 6/	120,000	100,000	120,000 r/	120,000
Bolivia	4,745	4,402	2,500	6,005	6,000
Bosnia and Herzegovina e/ 7/	500	2,000	2,000	2,000	2,000
Brazil (beneficiated)	39,662	51,961	46,632	44,906 r/	45,000
Burma	24,679	17,111	22,004	24,651	29,200
Canada	58,000	77,000	90,000	67,000 r/	20,000 p/
Chile	2,559	2,654	1,430	823 r/	900
China e/	2,800,000	3,500,000	3,300,000	3,500,000 r/	3,500,000
Colombia e/	6,800 6/	600	600	600	600
France e/	75,000	75,000	75,000	75,000 r/	75,000
Georgia e/	20,000	20,000	20,000	15,000	15,000
Germany (marketable Ba_2SO_4)	121,476	118,698	120,000 e/	120,000	120,000
Greece (crude ore)	671	905 r/	800 r/	800 r/	800
Guatemala e/	2,776 r/ 6/	2,800 r/	2,800 r/	2,800 r/	2,800
India	369,500	409,498	749,412	600,000	550,000
Iran 4/	150,000 e/	181,174	187,677 r/	183,850 r/	185,000
Italy	80,463	26,300	30,000 e/	25,000 e/	25,000
Kazakhstan 7/	50,000 e/	38,000 e/	9,000	13,300	14,000
Kenya e/	20	20	10	10	10
Korea, North e/	110,000	120,000	100,000	70,000	70,000
Korea, Republic of	80	105 e/	--	--	--
Laos e/	6,000	8,000	9,050	6,600	9,000
Malaysia	17,458	2,608	1,580 e/	13,506 r/	13,500
Mexico	470,028	236,606	161,555 r/	157,953 r/	127,688 p/
Morocco	288,308	343,314	353,438	350,000 r/	350,000
Nigeria e/	--	4,000	5,000	5,000	5,000
Pakistan	18,582	23,390	20,657	20,505 r/	21,234 6/
Peru	37,103	63,727 r/	7,506 r/	3,512 r/	11,403 p/ 6/
Poland	21,700	3,400	--	--	--
Romania e/	12,541 6/	12,000	15,000 r/	15,000 r/	15,000
Russia e/	70,000 6/	60,000	60,000	60,000	60,000
Saudi Arabia e/	8,000	8,000	8,000	7,000	8,000
Slovakia (concentrate)	45,000	62,000	15,000	16,000 r/	15,000
South Africa	7,428	2,071	610 e/	2,844 r/	1,628 6/
Spain e/	28,000	28,000	28,000	26,000	26,000
Thailand	48,074	54,817	96,241 r/	68,012 r/	49,220 6/
Tunisia	15,360	12,841	8,011	530 r/	3,702 6/
Turkey (run-of-mine)	104,872	226,594	160,042	130,000	130,000
United Kingdom	102,000	74,000	70,000 r/	68,000 r/	70,000
United States 8/	662,000	692,000	476,000	434,000	392,000
Total	6,090,000	6,780,000 r/	6,460,000 r/	6,360,000 r/	6,200,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 8, 2001.

3/ In addition to the countries listed, Bulgaria also produces barite, but available information is inadequate to make reliable estimates of output levels.

4/ Data are for fiscal year beginning March 21 of that stated.

5/ Based on an estimated 70% recovery factor.

6/ Reported figure.

7/ Barite concentrates.

8/ Sold or used by producers.

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BAUXITE AND ALUMINA

By Patricia A. Plunkert

Domestic survey data and tables were prepared by Micheal George, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Bauxite is a naturally occurring, heterogeneous material comprised primarily of one or more aluminum hydroxide minerals plus various mixtures of silica (SiO_2), iron oxide (Fe_2O_3), titania (TiO_2), aluminosilicates (clay, etc.), and other impurities in trace amounts. The principal aluminum hydroxide minerals found in varying proportions within bauxite are gibbsite [$Al(OH)_3$] and the polymorphs, boehmite and diaspore [both AlO(OH)].

Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical, and refractory. Of all bauxite mined, approximately 85% is converted to alumina (Al_2O_3) for the production of aluminum metal, an additional 10% goes to nonmetal uses as various forms of specialty alumina, and the remaining 5% is used for nonmetallurgical bauxite applications. The bulk of world bauxite production is, therefore, used as feed for the manufacture of alumina via a wet chemical caustic leach process known as the Bayer process. The majority of the alumina produced from this refining process is smelted using the Hall-Héroult process to produce aluminum metal by electrolytic reduction in a molten bath of natural or synthetic cryolite ($NaAlF_6$).

Specifications for the nonmetallurgical grades of bauxite are more stringent than those for bauxite used to produce metal and are based on the processing requirements and special properties required of their final commercial products. The natural chemical impurities that exist within these specialty-grade raw materials are not chemically removed by refining as is the case for metallurgical-grade bauxite. Nonmetallurgical ores in an essentially unrefined chemical form are used as direct feed for the production of their ultimate end products. Although figures on bauxite production and consumption within nonmetallurgical markets are not commonly available, the principal industrial end uses for nonmetallurgical-grade bauxite are considered to be in refractories and abrasives, followed by cement applications. In addition, the aluminum chemicals and steel industries also consume significant quantities of bauxite.

In 2000, 22 countries reported bauxite mine production, and total world production increased by 6% compared with that of 1999. Australia, Brazil, Guinea, and Jamaica accounted for about 70% of the total bauxite mined in 2000. The principal sources of nonmetallurgical-grade bauxite are limited to only a handful of countries: abrasive grade is produced in Australia, China, Greece, Guinea, Guyana, and Italy; refractory grade, in Brazil, China, and Guyana (Russell, 1999, p. 49, 58).

Total reported world reserves of bauxite are sufficient to meet cumulative world primary aluminum metal demand well into the 21st century. Although bauxite reserves are unevenly

Bauxite and Alumina in the 20th Century

In 1900, bauxite in the United States was mined in three States—Alabama, Arkansas, and Georgia. Production that year was about 23,600 metric tons. World bauxite production in 1900 totaled 88,000 tons and was derived from three countries; the largest producer was France (58,500 tons), followed by the United States and the United Kingdom (5,870 tons). Even in 1900, the United States was not self-sufficient in bauxite and imported 8,790 tons of bauxite, approximately 28% of U.S. consumption. Bauxite was used mainly for the manufacture of aluminum, although a considerable quantity was used for the manufacture of aluminum sulfate and crystalized alum. In order to produce aluminum commercially, bauxite was converted to alumina by the Bayer process, which was patented by Karl Josef Bayer in 1888 and is still used today. Data on domestic and world production levels of alumina in 1900 are not available. Reports, however, indicate that the Pittsburgh Reduction Company (Alcoa Inc.) operated an alumina plant in New Kensington, PA, in 1900.

In 2000, bauxite production in the United States was negligible and was used for nonmetallurgical applications. World bauxite mine production totaled about 135 million metric tons. Of the 22 countries that reported mine production, Australia, Brazil, Guinea, and Jamaica accounted for about 70% of the production. Of the bauxite mined worldwide, about 85% was converted to alumina by the Bayer process for producing aluminum metal. An additional 10% was used in nonmetallurgical applications in various forms of specialty alumina, and the remaining 5% was used for nonmetallurgical bauxite applications, such as abrasives, refractories, cement additives, and aluminum chemicals.

Domestic production of alumina in 2000 was derived almost exclusively from imported metallurgical-grade bauxite. An estimated 90% of the alumina shipped by U.S. refineries went to domestic primary smelters for aluminum metal production. Consumption by the abrasive, chemical, refractory, and specialty industries accounted for the remainder. Despite being one of the four largest alumina producers in the world, the United States depends on alumina imports for about one-half of its metallurgical requirements. Of the 28 countries that produced a total of more than 49 million tons of alumina, Australia dominated the industry and accounted for about one-third of total world production.

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distributed throughout the world, with approximately 90% in about a dozen countries, the sheer magnitude of these reserves (25 billion metric tons) is sufficient to ensure a readily accessible supply for the future (Plunkert, 2001).

U.S. production of alumina (calcined equivalent), derived almost exclusively from imported metallurgical-grade bauxite, decreased by 7% in 2000 compared with that of 1999. An estimated 90% of the alumina shipped by U.S. refineries went to domestic primary smelters for aluminum metal production. Consumption by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of U.S. alumina shipments.

World output of alumina increased 5% in 2000. The principal producing countries, in descending order of alumina output, were Australia, the United States, China, and Jamaica. These countries accounted for almost 60% of the world's production; Australia alone accounted for about one-third of total world production.

Legislation and Government Programs

In September, the Defense Logistics Agency (DLA) released its Annual Materials Plan (AMP) for the National Defense Stockpile (NDS) for fiscal year 2001. The 2001 AMP, including its subsequent revisions, provided for the sale of 3.05 million metric tons (Mt) (3 million long tons) of metallurgical-grade bauxite, of which 2.03 Mt (2 million long tons) was Jamaica type and 1.02 Mt (1 million long tons) was Suriname type (Defense Logistics Agency, 2000a). Also, as part of the plan, the DLA was authorized to dispose of 5,080 calcined tons (5,000 long calcined tons) of refractory-grade bauxite in fiscal year 2001 (Defense Logistics Agency, 2001b). These were the maximum amounts recommended for disposal during the fiscal year, and the actual level of sales was to be dependent upon the prevailing market conditions.

During calendar year 2000, the DLA announced the following sales of bauxite from the NDS: 10,200 metric tons (t) (10,000 long tons) of metallurgical-grade bauxite, Jamaica type, for a provisional value of $45,000 to Bulk Materials International (Defense Logistics Agency, 2000b); and 680,000 t (669,000 long tons) of metallurgical-grade, Suriname type, for an estimated value of $5.11 million to Alcoa Inc. and Bulk Materials Inc. (Defense Logistics Agency, 2000c).

At yearend, the NDS uncommitted inventory for metallurgical-grade bauxite was 5.5 Mt (5.42 million long tons) of Jamaica type and 201,000 t (197,000 long tons) of Suriname type. The NDS calcined refractory-grade bauxite inventory was 2,520 calcined tons (2,480 long calcined tons) (Defense Logistics Agency, 2001a).

Production

On May 3, Alcoa Inc. and Reynolds Metals Co. announced that the U.S. Department of Justice (DOJ) and the European Union (EU) had approved their proposed merger and that the merger had been completed. Reynolds shareholders had approved the merger on February 11. Under the terms of the consent decree entered into with the DOJ and an undertaking agreement with the EU, Alcoa was required to sell a 25% interest in Reynolds' Longview, WA, smelter, as well as Reynolds' interests in three alumina refineries—Worsley, Australia (56%); Stade, Germany (50%); and Sherwin, TX (100%). As a result of the merger, each outstanding share of Reynolds common stock was converted into 1.06 shares of Alcoa common stock (Alcoa Inc., 2000a).

On June 1, Alcan Aluminium Ltd. and algroup, the aluminum division of Alusuisse Lonza Group Inc., announced that, following the approval of the DOJ and the EU, the companies had reached agreement on their merger plan (Alcan Aluminium Ltd., 2000a). The EU gave its approval subject to commitments made by the companies to alleviate the EU's competition concerns in the aluminium trihydrate (ATH) market. Among its commitments, Alcan proposed selling algroup's ATH facility in Martinswerk, Germany, and the algroup lithography operations in Bridgenorth, United Kingdom (Platt's Metals Week, 2000a). The merger, which involved the combination of a cash payment and the exchange of 17.1 Alcan common shares for every algroup share, was finalized on October 17 (Alcan Aluminium Ltd., 2000b).

Bauxite.—For many years, domestic mines have supplied less than 1% of the U.S. requirement for bauxite. Essentially all the domestic bauxite production is used in nonmetallurgical products, such as abrasives, chemicals, proppants, and refractories. Thus, the United States imports almost all the bauxite, especially the metallurgical grade, that it requires.

Alumina.—Alcoa sold its 1.6-million-metric-ton-per-year (Mt/yr) Sherwin alumina refinery located near Corpus Christi, TX, to BPU Reynolds, Inc., a private investment company. The sale of the former Reynolds facility was required under the DOJ regulatory approval that cleared Alcoa's acquisition of Reynolds (Alcoa Inc., 2000b). According to the Corpus Christi Caller Times, the name BPU Reynolds derives from its four principal investors: former Reynolds Metals vice chairman Randy Reynolds; Peter Bailey, a former Alcoa executive who managed Alcoa's Point Comfort alumina refinery and its alumina chemical sales; retired Alcoa sales executive Lewis Paterson; and Mark Uzelac, a former Westinghouse executive (Metal Bulletin, 2000b).

In July 1999, Kaiser Aluminum & Chemical Corp.'s 1.05-Mt/yr Gramercy, LA, alumina refinery was extensively damaged by an explosion in the digestion area of the plant. Repairs on the damaged part of the plant began during the first quarter of 2000. Initial production at the plant commenced during the middle of December 2000, and production was expected to increase progressively throughout 2001. At the end of February 2001, the plant was operating at 70% of its newly rated capacity of 1.25 Mt/yr. Construction at the facility was expected to be completed during the third quarter of 2001 (Kaiser Aluminum & Chemical Corp., 2001, p. 16).

Alcoa announced the temporary closure of its 600,000-metric-ton-per-year (t/yr) alumina refinery at St. Croix, U.S. Virgin Islands. The plant, which had been operating since December 1997 and sold alumina to Alcoa-operated smelters in the United States, ceased production at the end of January 2001 (Alcoa Inc., 2000d).

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Consumption

Bauxite.—Total domestic consumption of bauxite decreased by about 9% compared with that of 1999. Most of the decrease in consumption was accounted for by the continued loss of alumina production at the damaged Gramercy refinery. In 2000, 95% of the bauxite consumed in the United States was refined to alumina (an estimated 2.1 t of dried bauxite was required to produce 1 t of alumina); the remaining 5% was consumed in nonmetallurgical applications (table 4). Domestic production and consumption data for bauxite and alumina were obtained by the U.S. Geological Survey from three separate, voluntary surveys of U.S. operations. Typical of these surveys is "Bauxite Consumption," sent to 47 operations, 34 of which responded, representing 75% of total bauxite consumption listed in table 4.

C-E Minerals Inc. purchased North American Processing Co., which was renamed C-E Minerals Processing. The 68,000-t/yr plant in Newell, WV, processes refractory minerals such as bauxite, brown fused alumina, magnesite, magnesia, and silicon carbide (Industrial Minerals, 2000a).

Resco Products Inc. entered the refractory brick market following the purchase of certain divested assets from RHI Refractories America Inc. Resco acquired the former Harbison-Walker Refractories Co. plants in Hammond, IN, and Marelan, Quebec, as well as a number of product lines from the RHI plant in Farber, MO, and the former Harbison-Walker facility in Windham, OH. The divestitures were required for U.S. Federal Trade Commission (FTC) approval of RHI's acquisition of Global Industrial Technologies, Inc., in 1999 (The Refractories Institute, 2000).

Having made the required FTC divestitures, RHI began restructuring its North American operations. In April, a $10 million capital improvement program, which included the addition of three new hydraulic brick presses, related support equipment, and a minor plant expansion, was begun at the Windham, OH, facility. Plants in Curwensville and Wolmelsdorf, PA; Farber, MO; and Northeast, MD, were closed (Industrial Minerals, 2000c).

Alumina.—An estimated 90% of the alumina shipped by U.S. alumina plants went to domestic primary aluminum smelters for metal production. In 2000, 23 primary aluminum smelters consumed 7.16 Mt of alumina. Consumption in various forms by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of U.S. alumina use.

Prices

Most metallurgical-grade bauxite and alumina are purchased under long-term contracts. Contract terms for these commodities normally are not made public. Spot prices for metallurgical-grade alumina and specialty forms of bauxite and alumina for nonmetallurgical applications, however, are published in trade journals.

Industrial Minerals (2000b) quoted end-of-year prices for several types of imported refractory-grade bauxite from China and Guyana. The price quotes for Chinese refractory-grade bauxite, minimum 87% Al_2O_3 free on board (f.o.b.) Chinese ports, were as follows: Shanxi, shaft, lump, $71 to $75 per ton; Shanxi rotary, lump, $85 to $90 per ton; and Guizhou, round, lump, $70 to $73 per ton. The price ranges for Guyanese refractory-grade bauxite were as follows: $155 to $175 per ton, f.o.b. barge, U.S. Gulf Coast; and $165 to $175 per ton, cost, insurance, and freight (c.i.f.) Europe.

The 2000 annual average values of U.S. imports of metallurgical-grade bauxite are listed in table 7.

The market or spot prices for alumina continued to increase during the first four months of 2000, a trend that began in April 1999, then fell dramatically through December 2000. According to Metal Bulletin, metallurgical-grade alumina spot prices on international markets began 2000 at $375 to $385 per ton. The price range increased to $420 to $440 per ton in mid-February and held steady at this range through mid-May before beginning a precipitous decline through the end of the year. By yearend, the price range had decreased to $165 to $175 per ton. Trade data released by the U.S. Census Bureau indicated that the average annual value of U.S. imports of calcined alumina was $226 per ton, free alongside ship (f.a.s.) port of shipment, and $238 per ton, c.i.f. U.S. ports.

Trade

In addition to the trade data listed in tables 8-10, various specialty aluminum compounds were also exported from and imported to the United States. The compounds exported included 7,690 t of aluminum sulfate, 19,600 t of aluminum chloride, 9,020 t of aluminum oxide abrasives, and 5,550 t of various fluoride-based compounds of aluminum, including synthetic cryolite and aluminum fluoride. The compounds imported included 23,500 t of aluminum sulfate, 1,700 t of aluminum chloride, 120,000 t of aluminum oxide abrasives, and 21,500 t of various fluoride-based aluminum compounds.

World Review

In 2000, world production of bauxite increased 6% compared with that of 1999 (table 11). Mine production was reported in 22 countries, and total world production amounted to more than 135 Mt. The largest producers of bauxite, in decreasing order of tonnage mined, continued to be Australia, Guinea, Brazil, and Jamaica, accounting for about 70% of total world production.

World output of alumina increased 5% in 2000 compared with that of 1999 (table 12). The four principal producing countries, in order of quantity of alumina produced, were Australia, the United States, China, and Jamaica. These countries accounted for almost 60% of the world's production; Australia alone accounted for about one-third.

Australia.—Comalco Ltd. selected Gladstone in Queensland as the site for its proposed new $850 million ($1.4 billion Australian) alumina refinery. The company will conduct a final feasibility study to evaluate the project's long-term viability including commercial, technical, and environmental aspects (Comalco Ltd., 2000).

Comalco and its partners in Queensland Alumina Ltd. [Comalco (30.3%), Kaiser (28.3%), Alcan (21.4%), and Pechiney (20%)] also were examining prospects for an expansion of their existing Gladstone refinery, which is the

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world's largest alumina refinery with 3.74-Mt/yr capacity. With the acquisition of the remaining publicly held shares (27.6%) of Comalco, Rio Tinto plc became the company's sole owner during the first half of 2000 (Rio Tinto plc, 2001, p. 39).

Alcan acquired the remaining 30% of the Gove alumina refinery and related bauxite mine making it the sole owner of these assets. Annual capacity of the Gove refinery, located in the Northern Territory, was 1.8 Mt (Alcan Aluminium Ltd., 2001a).

Worsley Alumina Pty Ltd. completed the $1 billion expansion of its alumina refinery south of Perth. The expansion, which included the construction of a $45 million gas-fired cogeneration plant to meet the refinery's higher steam and electricity requirements, increased alumina production capacity to 3.1 Mt from 1.22 Mt (Hagopian, 2000; Metal Bulletin, 2000l).

Alcoa and Billiton plc reached an agreement whereby Billiton would acquire Reynolds Australia Alumina, Ltd. LLC, which held a 56% interest in the Worsley alumina refinery, Western Australia, for $1.49 billion. Alcoa had acquired the stake in Worsley as part of its acquisition of Reynolds Metals, and was required to sell the Worsley interest as a condition of U.S. and European antitrust approval of the Reynolds Metals acquisition (Alcoa Inc., 2000c). The sale was completed in January 2001. As a result, Billiton increased its share of Worsley to 86% and the remaining 14% was owned by Kobe Steel Ltd., Nissho Iwai Corp., and Itochu Corp. (Alcoa Inc., 2001).

Azerbaijan.—The Government of Azerbaijan united three state-owned plants—the Sumgait aluminium smelter, the Gyandzha alumina plant, and Alunite Ore Mining Co.—into a single holding company, Azeraluminy JSC. The Government then invited tenders for a management contract for these plants (Metal Bulletin, 2000c). Fondel Metal Participants, a Dutch company, won a tender for the long-term management of Azeraluminy. Fondel reportedly agreed to invest $1 billion in the company and to modernize and expand production capacity at the 50,000-t/yr Sumgait smelter, the 450,000-t/yr Gyandzha refinery, and a bauxite mine (CRU Alumina Monitor, 2000).

Brazil.—Construction work on an 800,000-t/yr expansion has begun at the Alumina do Norte do Brazil S.A. (Alunorte) 1.5-Mt/yr alumina refinery. Brazil's National Development Bank would finance 70% of the cost, and the partners in Alunorte with the exception of the Japanese Consortium would finance the remainder. The remaining partners were Norsk Hydro ASA (25.25%), Mineração Rio do Norte (MRN) (12.62%), and Cia. Brasileira de Aluminio (CBA) (3.62%). Production was expected to begin at the end of 2002 and full production from the expansion would be available by mid-2003 (Mining Journal, 2000a).

The equity partners in MRN's Trombetas bauxite mine approved an expansion that would increase production by about 50% to 16.3 Mt/yr from 11 Mt/yr by 2003 (Alcan Aluminium Ltd., 2001b, p. 31). Alumina refinery expansions will require an increase in bauxite feed material, and this mine expansion should help to meet the increased demand. MRN's shareholders are Companhia Vale do Rio Doce (40%), Alcoa (13.12%), Billiton (12.5%), Alcan (12.5%), CBA (12.5%), Norsk Hydro (5%), and Abalco SA (4.37%) (Metal Bulletin, 2000d).

China.—Company officials reported that Pingguo Aluminium Co. had completed all of the financing and was awaiting final Government approval to start its phase 2 alumina expansion. The project would increase Pingguo's refinery production capacity to about 800,000 t/yr from 350,000 t/yr. The project was expected to take 3 years to complete, after which an additional expansion to 1.25 Mt/yr is planned (Platt's Metals Week, 2000b).

Guinea.—Russia's Sibirsky Aluminy (now part of Russky Aluminy) signed an agreement with the State Bauxite Co. of Guinea for a long-term supply of bauxite. Under the agreement, Guinea will supply bauxite to Sibirsky's alumina refineries in Russia and the Ukraine in exchange for mining equipment (Metal Bulletin, 2000k).

Hungary.—Magyar Aluminium Rt (MAL) integrated its 100%-owned affiliates (Ajkai Timfold Kft, owner of the 280,000-t/yr Ajka alumina refinery, and Inotai Aluminium Kft, owner of the 35,000-t/yr Inota aluminum smelter) into one holding company to reduce administrative costs and to simplify strategic planning (CRU Aluminium Monitor, 2000).

India.—Alcan sold its 54.6% stake in Indian Aluminium Co. Ltd. (Indal) to Hindalco Industries Ltd. Included in the sale was Alcan's share of production from Indal's 90,000-t/yr refinery at Muri and the 250,000-t/yr refinery at Belgaum (Metal Bulletin, 2000a).

National Aluminium Co. Ltd. (Nalco) completed the first phase of its alumina expansion program. Debottlenecking at its 800,000-t/yr Damanjodi refinery increased capacity to 1.05 Mt/yr of alumina. The company planned to further expand capacity to 1.575 Mt/yr in 2001. In addition, production capacity at Nalco's open pit bauxite mine on the Panchpatmali hills of the Koraput District in Orissa was doubled to 4.8 Mt/yr from 2.4 Mt/yr (National Aluminium Co. Ltd., Operations, accessed August 3, 2001, at URL http://nalcoindia.com/invdefault.htm).

Kazakhstan.—Kazakhstan Mineral Resources Group announced plans to increase production capacity at its 1.2 Mt/yr Pavlodar alumina refinery to 1.5 Mt/yr by 2005. The company expected to steadily increase the annual production levels by technological upgrades and the installation of new equipment without changing the existing process (Metal Bulletin, 2000e).

Romania.—Russky Aluminy (Russian Aluminium), which took control of operations at the Oradea refinery, restarted the plant using imported Australian bauxite. Russian Aluminium expected to continue to increase production during 2001 and to reach production capacity of 250,000 t/yr in 2002. In later years, annual capacity at the refinery may be increased to 300,000 to 350,000 t/yr (Metal Bulletin, 2000h).

Russia.—A new aluminum company, Russky Aluminy (Russian Aluminium), was formed by combining the assets of the Sibneft shareholder group and Siberian Aluminium. Russian Aluminium manages about 70% of Russia's primary aluminum smelting capacity. The company controls Russia's three largest smelters—Bratsk (900,000 t/yr), Krasnoyarsk (800,000 t/yr), and Sayansk (400,000 t/yr). As for alumina production, the company controls the Achinsk (900,000 t/yr) and the Nikolayev (1.05 Mt/yr) refineries. The downstream operations that are either fully or partly owned by the company include the Samara Metallurgical Plant, the Sayanal foil mill, the Rostar can plant, and the Belaya Kalitva Metallurgical

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Production Assn. (Metal Bulletin, 2000j).

A second new group, SUAL Holding, resulted from a merger of the aluminum assets of Siberian-Urals Aluminium Co. and the Trustconsult Group. SUAL controls the Irkutsk (262,000 t/yr), Bogoslovsk (162,000 t/yr), Uralsky (70,000 t/yr), and Kandalaksa (63,000 t/yr) primary aluminum smelters. The company also owns the Bogoslovsk (930,000 t/yr) and Uralsky (570,000 t/yr) refineries, the Northern and Southern Urals bauxite mines, and the Sredny-Timan bauxite deposits (CRU Alumina Monitor, 2000). Downstream facilities include the Kamensk-Uralsky Metallurgy Plant (rolling mill), the Mikhailovsky Nonferrous Metal Processing Plant (Mikhalum foil plant), and the Irkutsk and Kirinsky cable plants (Interfax Mining & Metals Report, 2000b).

SUAL announced plans to expand production at the Sredny-Timan deposit to 2.5 Mt/yr by 2005. An annual capacity of 6.5 Mt was planned by 2020. The mined bauxite provides raw material for the Uralsky refinery. The ore is moved by truck over an ice field during the winter, but a new rail track is under construction to provide year-round transport. The company reported that a new refinery could be built at the mine site to produce alumina for sale to other Russian producers in the future. Explored reserves at the deposit were estimated at 250 Mt (Interfax Mining & Metals Report, 2000c, d).

Russian Aluminum announced plans to invest about $6.5 million (193 million rubles) to increase production at the Achinsk alumina refinery to meet its engineered capacity of 900,000 t/yr. The first phase of the upgrade was used to buy new equipment for the plant's nepheline mines. Production in 1999 was estimated at 770,000 t. The company planned to reach full production levels in 2002 (Metal Bulletin, 2000i).

The 268,000-t/yr Pikalevo alumina refinery signed a new 5-year supply agreement with Apatit, a supplier of nepheline concentrates. Apatit resumed concentrate shipments and agreed to supply 90,000 t of concentrates per month over the life of the contract. The Pikalevo refinery supplies the Vogograd and Volklov smelters (Interfax Mining & Metals Report, 2000a).

Ukraine.—Ukrainian Aluminium Co., a subsidiary of Russian Aluminium, reported that contracts were signed for 1.6 Mt of bauxite from Brazil, Guyana, India, and Italy to supply the 1.05 Mt/yr Nikolayev alumina refinery. Additional supply contracts with Australia, Guinea, Sierra Leone, and Venezuela were also being negotiated (Metal Bulletin, 2000g).

Ukrainian Aluminium also submitted plans for expanding capacity at the Nikolayev refinery to 1.5 Mt/yr. The expansion reportedly would involve upgrading the existing facility, rather than requiring additional construction (Metal Bulletin, 2000f).

Venezuela.—Pechiney signed a contract to invest $260 million over 3 years in Bauxilum, Venezuela's state-owned bauxite and alumina producer. The upgrade program would increase capacity at the 1.7 Mt/yr alumina refinery to 2.1 Mt/yr. Pechiney would not have a direct interest in Bauxilum, but would receive its investment return in the form of the 400,000 t/yr of additional alumina production (Mining Journal, 2000b).

Outlook

Identified world bauxite reserves are sufficient to meet cumulative world demand well into the 21st century. Considering the probability of discovering additional bauxite deposits plus the added possibility of employing lower grade bauxite occurrences and various alternative sources of alumina, world resources of aluminum remain adequate to satisfy demand for the foreseeable future.

Weakness in the national economies of most areas of the world will restrict growth and possibly decrease demand for aluminum in 2001. Most forecasters, however, anticipate that this weakness will be short-lived and that demand will pick up in 2002 and thereafter. The automotive and construction industries will continue to be the major drivers for aluminum use. Overall, world demand is expected to grow, despite a possible drop in the growth rate for the next year or so as the world economies begin their recoveries.

As for aluminum metal production, energy costs and shortages continued to force companies to idle smelter capacity during the first half of 2001. Additional production from newly commissioned smelters and brownfield expansions should keep world metal supply and demand fairly balanced in 2001. However, the alumina market ended 2000 in an oversupply condition that continued during the first half of 2001. Despite increased exports of alumina by Western refiners to both the Chinese and Russian markets, this oversupply situation in the alumina market is likely to continue until aluminum metal demand and production increase.

References Cited

Alcan Aluminium Ltd., 2000a, Alcan and algroup to merge: Montreal and Zurich, Alcan Aluminium Ltd. press release, June 1, 2 p.

———2000b, Merger a success, launch of the new Alcan: Montreal and Zurich, Alcan Aluminium Ltd. press release, October 8, 2 p.

———2001a, Alcan completes acquisition of Gove refinery and mine: Montreal, Alcan Aluminium Ltd. press release, February 1, 1 p.

———2001b, Annual report—2000: Montreal, Alcan Aluminium Ltd., 80 p.

Alcoa Inc., 2000a, Alcoa completes merger with Reynolds Metals: Pittsburgh and Richmond, Alcoa Inc. press release, May 3, 1 p.

———2000b, Alcoa reaches agreement to sell Sherwin alumina refinery: Pittsburgh, Alcoa Inc. press release, October 20, 1 p.

———2000c, Alcoa reaches agreement to sell stake in Worsley alumina to Billiton: Pittsburgh and London, Alcoa Inc. press release, August 29, 1 p.

———2000d, Alcoa to suspend operations at St. Croix refinery: Pittsburgh, Alcoa Inc. press release, November 2, 1 p.

———2001, Alcoa completes sale of Worsley alumina refinery: Pittsburgh, Alcoa Inc. press release, January 25, 1 p.

Comalco Ltd., 2000, Comalco chooses Gladstone as site for alumina refinery feasibility study: Brisbane, Australia, Comalco Ltd. press release, April 3, 1 p.

CRU Alumina Monitor, 2000, Industry news: CRU Alumina Monitor, October, p. 6.

CRU Aluminium Monitor, 2000, Industry news: CRU Aluminium Monitor, November, p. 11.

Defense Logistics Agency, 2000a, Annual Materials Plan for FY 2001: Fort Belvoir, VA, Defense Logistics Agency news release, September 26, 2 p.

———2000b, Stockpile accepts metallurgical grade, Jamaican type bauxite offers: Fort Belvoir, VA, Defense Logistics Agency news release, March 1, 1 p.

———2000c, Stockpile accepts Surinam type bauxite offers: Fort Belvoir, VA, Defense Logistics Agency news release, December 14, 1 p.

———2001a, Inventory of stockpile material M-1: Defense Logistics Agency, January 16, 3 p.

———2001b, Revised FY 2001 Annual Materials Plan: Fort Belvoir, VA, Defense Logistics Agency news release, April 9, 2 p.

Hagopian, Arthur, 2000, Worsley completes expansion: American Metal Market, v. 108, no. 139, July 20, p. 4.

Industrial Minerals, 2000a, C-E Minerals buys NAPCO: Industrial Minerals, no. 388, January, p. 8.

Digitized by Google

———2000b, Prices: Industrial Minerals, no. 399, December, p. 74.
———2000c, Resco snaps up RHI refractory assets: Industrial Minerals, no. 393, June, p. 17, 19.
Interfax Mining & Metals Report, 2000a, Apatit to resume supplies to Glinozyom alumina plant: Interfax Mining & Metals Report, v. 9, issue 33, August 11-17, p. 13.
———2000b, Russia's second largest aluminum holding company set up: Interfax Mining & Metals Report, v. 9, issue 38, September 15-21, p. 3-4.
———2000c, SUAL, Transconsult may merge aluminum assets in Fall: Interfax Mining & Metals Report, v. 9, issue 15, April 7-13, p. 8-9.
———2000d, Timan bauxites provide a fifth of Uralsky alumina raw material: Interfax Mining & Metals Report, v. 9, issue 17, April 21-27, p. 9-10.
Kaiser Aluminum & Chemical Corp., 2001, Annual report—2000: Houston, Kaiser Aluminum & Chemical Corp., 64 p.
Metal Bulletin, 2000a, Alcan withdraws from India to focus on flat-rolled opportunities: Metal Bulletin, no. 8462, March 27, p. 9.
———2000b, Alcoa finalises sale of Sherwin refinery: Metal Bulletin, no. 8520, October 26, p. 6.
———2000c, Azerbaijan seeks investors to manage Al business: Metal Bulletin, no. 8471, May 1, p. 7.
———2000d, Brazil's MRN studies major bauxite expansion: Metal Bulletin, no. 8473, May 8, p. 5.
———2000e, Kazakhstan alumina refinery raises output: Metal Bulletin, no. 8526, November 16, p. 4.
———2000f, Nikolayev refinery to raise output: Metal Bulletin, no. 8486, June 22, p. 7.
———2000g, Nikolayev secures bauxite supplies: Metal Bulletin, no. 8447, February 3, p. 3.
———2000h, Romanian refinery restarts production: Metal Bulletin, no. 8531, December 4, p. 4.
———2000i, Russky Aluminy plans to raise output at Achinsk: Metal Bulletin, no. 8480, June 1, p. 9.
———2000j, Russky Aluminy works on consolidating assets, building market share and developing alumina: Metal Bulletin, no. 8495, July 24, p. 6.
———2000k, Sibirsky's bauxite deal: Metal Bulletin, no. 8485, June 19, p. 18.
———2000l, Worsley expands Australia's output: Metal Bulletin Monthly, Aluminium supplement, no. 357, September, p. 34-35.
Mining Journal, 2000a, Alunorte expansion—construction begins: Mining Journal, v. 335, no. 8606, October 27, p. 338.
———2000b, Pechiney signs Venezuelan contract: Mining Journal, v. 335, no. 8612, December 8, p. 445.
Platt's Metals Week, 2000a, EC forces rethink of Alcan-Pechiney merger plan: Platt's Metals Week, v. 71, no. 12, March 20, p. 1, 10-11.
———2000b, Pingguo to start phase two expansion: Platt's Metals Week, v. 71, no. 48, November 27, p. 8.
Plunkert, P.A., 2001, Bauxite and alumina: U.S. Geological Survey Mineral Commodity Summaries 2001, p. 28-29.
Rio Tinto plc, 2001, Annual report—2000: London, Rio Tinto plc, 136 p.
Russell, Alison, 1999, Bauxite & alumina—A guide to non-metallurgical uses and markets: Surrey, United Kingdom, Metal Bulletin plc, 112 p.
The Refractories Institute, 2000, Resco Products Inc. acquires RHI assets: Refractory News, v. 3-00, March, p. 1.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Aluminum. Ch. in Mineral Commodity Summaries, annual.
Aluminum. Mineral Industry Surveys, monthly.
Aluminum and Bauxite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Bauxite and Alumina. Ch. in Mineral Commodity Summaries, annual.
Primary Aluminum Plants Worldwide, 1998.
U.S. Trade in Bauxite and Alumina. Mineral Industry Surveys, quarterly.
World Bauxite Resources, Professional Paper 1076-B, 1986.
World Nonbauxite Aluminum Resources—Alunite. Professional Paper 1076-A, 1978.
World Nonbauxite Aluminum Resources Excluding Alunite, Professional Paper 1076-C, 1990.

Other

Aluminum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Alumina Plants Worldwide, U.S. Bureau of Mines, 1993.
Bauxite Mines Worldwide, U.S. Bureau of Mines, 1994.
CRU. Alumina Monitor (monthly).

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TABLE 1
SALIENT BAUXITE STATISTICS 1/

(Thousand metric tons)

	1996	1997	1998	1999	2000
United States:					
Production, crude ore (dry equivalent)	W	NA	NA	NA	NA
Value	W	NA	NA	NA	NA
Exports (as shipped):					
Crude and dried	92	64	83	115	133
Calcined	40	21	16	34	9
Imports for consumption (as shipped):					
Crude and dried	10,200	10,700	11,000	9,890	8,550
Calcined	352	369	393	299	310
Consumption (dry equivalent)	11,000	11,500	12,700	11,700	10,600
World, production	117,000	122,000	122,000	128,000 r/	135,000 e/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits.

TABLE 2
ESTIMATED PRODUCTION AND SHIPMENTS OF ALUMINA IN THE UNITED STATES 1/

(Thousand metric tons)

			Total	
Year	Calcined alumina	Other alumina 2/	As produced or shipped 3/	Calcined equivalent
Production:				
1998	5,100	820	5,920	5,650 r/
1999	4,620	780	5,400	5,140 r/
2000	4,310	691	5,000	4,780
Shipments:				
1998	5,080	822	5,910	5,640 r/
1999	4,600	780	5,380	5,130 r/
2000	4,300	691	4,990	4,770

r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.
3/ Includes only the end product if one type of alumina was produced and used to make another type of alumina.

TABLE 3
CAPACITIES OF DOMESTIC ALUMINA PLANTS, AS OF DECEMBER 31, 2000 1/ 2/

(Thousand metric tons per year)

Company and plant	1999	2000
Alcoa Inc.:		
Point Comfort, TX	2,300	2,300
St. Croix, VI 3/	600	600
Total	2,900	2,900
BPU Reynolds, Inc., Corpus Christi, TX	1,600	1,600
Kaiser Aluminum & Chemical Corp., Gramercy, LA	(4/)	1,250 4/
Ormet Corp., Burnside, LA	600	600
Grand total	5,100	6,350

1/ Capacity may vary depending on the bauxite used.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Temporarily shutdown.
4/ Damaged in an explosion, partial restart in December 2000.

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TABLE 4
U.S. CONSUMPTION OF BAUXITE, BY INDUSTRY 1/

(Thousand metric tons, dry equivalent)

Industry	1999	2000
Abrasive	113	111
Alumina	11,100	10,100
Chemical	W	W
Refractory	251	160
Other 2/	229	225
Total	11,700	10,600

W Withheld to avoid disclosing company proprietary data; included with "Other.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes cement, municipal water works, oil, and steel and ferroalloys.

TABLE 5
STOCKS OF BAUXITE IN THE UNITED STATES, DECEMBER 31 1/ 2/

(Thousand metric tons, dry equivalent)

Sector	1999	2000
Producers, processors, consumers	1,440	1,300
Government	6,800	5,710
Total	8,250	7,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Domestic and foreign bauxite; crude, dried, calcined, activated, all grades.

TABLE 6
STOCKS OF ALUMINA IN THE UNITED STATES, DECEMBER 31 1/ 2/

(Thousand metric tons, calcined equivalent)

Sector	1999	2000
Producers	349	334
Primary aluminum plants	959 r/	950
Total	1,310 r/	1,290

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes consumers stocks other than those at primary aliminum plants.

TABLE 7
AVERAGE VALUE OF U.S. IMPORTS OF CRUDE AND DRIED BAUXITE 1

(Per metric ton)

	1999		2000	
Country	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
Australia	$12.11	$20.09	$13.50	$25.53
Brazil	24.32	31.15	23.51	29.82
Guinea	22.37	28.81	23.05	29.09
Guyana	24.58	35.66	26.01	36.80
Jamaica	17.05	23.93	19.53	24.97
Weighted average	21.56	28.67	23.09	29.94

1/ Computed from quantity and value data reported to U.S. Customs Service and compiled by the U.S. Census Bureau, Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF BAUXITE, CRUDE AND DRIED, BY COUNTRY 1/

(Thousand metric tons)

Country	1999	2000
Imports: 2/		
Australia	59	108
Brazil	1,520	1,560
Guinea	4,060	3,350
Guyana	1,010	1,020
Jamaica 3/	2,800	2,120
Other	456	391
Total	9,890	8,550
Exports:		
Canada	99	128
Mexico	11	2
Other	5	3
Total	115	133

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes bauxite imported to the U.S. Virgin Islands from foreign countries.
3/ Dry equivalent of shipments to the United States.

NOTE: Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands), as reported by the U.S. Census Bureau, were as follows: 1999--8,900,000 tons and 2000--6,800,000 tons.

Sources: U.S. Census Bureau and the Jamaica Bauxite Institute.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF CALCINED BAUXITE, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

	1999				2000			
	Refractory grade		Other grade		Refractory grade		Other grade	
Country	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Imports:								
Australia	--	--	22	2,380	--	--	28	2,740
Brazil	33	5,110	1	117	9	934	11	1,070
China	75	5,810	94	7,110	117	9,440	82	6,200
Guyana	42	4,700	12	1,010	36	4,100	8	613
Other	17	1,550	2	162	20	1,460	(3/)	29
Total	167	17,200	132	10,800	181	15,900	129	10,700
Exports:								
Canada	2	514	5	434	1	237	4	363
Japan	17	3,480	--	--	--	--	--	--
Mexico	6	1,170	(3/)	96	1	208	(3/)	67
Other	1	307	1	570	1	327	1	596
Total	27	5,470	7	1,100	4	772	5	1,030

-- Zero.
1/ Data are rounded to no more three significant digits; may not add to totals shown.
2/ Value at foreign port of shipment as reported to U.S. Customs Service.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF ALUMINA, BY COUNTRY 1/

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Imports:				
Australia	2,380	430,000	2,440	497,000
Brazil	44	18,900	126	30,000
Canada	92	58,800	100	60,600
France	11	19,000	14	19,900
Germany	64	71,600	65	78,000
India	135	21,300	131	26,300
Jamaica	357	60,600	276	55,100
Japan	7	12,900	13	15,200
Suriname	580	95,300	559	105,000
Trinidad and Tobago	31	4,990	--	--
Venezuela	56	18,700	10	4,290
Other	48	32,700	86	41,000
Total	3,810	845,000	3,820	933,000
Exports:				
Brazil	1	2,040	1	2,080
Canada	923	224,000	990	263,000
China	27	7,310	1	2,680
Finland	(3/)	318	(3/)	772
Mexico	189	46,400	42	28,400
Netherlands	5	5,140	4	5,840
Norway	(3/)	218	(3/)	108
Russia	(3/)	97	(3/)	76
Sweden	(3/)	897	1	1,090
Other	88	148,000	47	148,000
Total	1,230	435,000	1,090	452,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Value at foreign port of shipment as reported to the U.S. Customs Service.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 11
BAUXITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000
Albania e/	1	1	--	--	--
Australia	43,063	44,465	44,553	48,416	53,802
Bosnia and Herzegovina e/	75	75	75	75	75
Brazil	10,998	11,671	11,961	13,839 r/	14,000 e/
China e/	6,200	8,000	8,200	8,500	9,000
Ghana	473	519	443	355 r/	504
Greece	2,452	1,877	1,823	1,883	1,991
Guinea e/ 3/	15,600	16,400	15,000	15,000	15,000
Guyana 3/	2,475	2,467	2,267 r/	2,359 r/	2,404
Hungary	1,044	743	1,138 r/	935 r/	1,047
India	5,757	6,019	6,102	6,712 r/	7,366
Indonesia	842	809	1,056	1,116	1,200 e/
Iran e/	150	150	336 r/ 4/	912 r/ 4/	1,000
Jamaica 3/ 5/	11,863	11,987	12,646	11,688	11,127
Kazakhstan	3,140 e/	3,380 e/	3,437	3,607	3,727
Malaysia	219	279	160	224 r/	123
Mozambique	11	8	6	8 r/	8
Pakistan	4	5	5	11	9
Romania	175	127	162	--	--
Russia e/	3,300	3,350	3,450	3,750	4,200
Serbia and Montenegro	323	470	226	500	630
Suriname	3,695	3,877	3,890 r/	3,715 r/	3,610
Turkey 6/	545	369	458	208 r/	459
United States	W	NA	NA	NA	NA
Venezuela	4,834	4,967	4,826	4,166 r/	4,200 e/
Total	117,000	122,000	122,000	128,000 r/	135,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 25, 2001.

3/ Dry bauxite equivalent of crude ore.

4/ Reported figure.

5/ Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

6/ Public-sector production only.

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TABLE 12
ALUMINA: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Australia	13,348	13,385	13,853	14,532	15,681 4/
Azerbaijan e/	5	10	(5/)	50 r/ 4/	200
Bosnia and Herzegovina e/	50	50	50	50	50
Brazil	2,752	3,088	3,322	3,515 r/	3,500
Canada	1,060	1,165	1,229	1,233	1,200
China e/	2,550	2,940	3,330	3,840	4,330 4/
France	440	454	450 e/	400 e/	400
Germany	755	738	600 r/ e/	583 r/	700
Greece e/	602 4/	602	600	600	600
Guinea e/	640	650 4/	480	500	550
Hungary	208	76	138	145 r/	150
India e/	1,780	1,860	1,890	1,900	2,000
Ireland	1,234	1,273	1,200 e/	1,200 e/	1,200
Italy	881	913	930	973	950
Jamaica	3,200	3,394	3,440	3,570	3,600
Japan 6/	337	368	359	335 r/	340
Kazakhstan	1,083	1,095	1,085	1,152	1,200
Romania	261	282	250	277	417 4/
Russia	2,105	2,400 e/	2,465	2,657	2,850
Serbia and Montenegro	186	160 e/	153	156	250
Slovakia e/	100	100	100	100	100
Slovenia	88	85	70 e/	70 e/	70
Spain 7/	1,095	1,110	1,100 e/	1,200 e/	1,200
Suriname e/	1,600	1,600	1,600	-- r/	-- 4/
Turkey	159	164	157	159 r/	155 4/
Ukraine	1,000 e/	1,080 e/	1,291	1,230	1,360 4/
United Kingdom	99	100 e/	96	90 r/	100
United States	4,700	5,090	5,650 r/	5,140 r/	4,780 4/
Venezuela	1,701	1,730	1,553	1,335	1,400
Total	44,000	46,000	47,400 r/	47,000 r/	49,300

e/ Estimated. r/ Revised. -- Zero.

1/ Figures represent calcined alumina or the total of calcined alumina plus the calcined equivalent of hydrate when available; exceptions, if known, are noted.

2/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

3/ Table includes data available through July 25, 2001.

4/ Reported figure.

5/ Production sharply curtailed or ceased.

6/ Data presented are for alumina used principally for specialty applications. Information on aluminum hydrate for all uses is not adequate to formulate estimates of production levels.

7/ Hydrate.

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BERYLLIUM

By Larry D. Cunningham

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Beryllium (Be), silver in color and one of the lightest of all metals, has one of the highest melting points (about 1,280° C) of all light metals. It has physical and chemical properties, such as its stiffness, resistance to corrosion from acids, and electrical and thermal conductivity, that make it useful for various applications in its alloyed, oxide, and metallic forms. Only two beryllium minerals, beryl and bertrandite, are of commercial importance; beryl contains about 4% Be and bertrandite contains less than 1% Be. Bertrandite is the principal beryllium mineral mined in the United States, and beryl is the principal mineral produced in the rest of the world.

In 2000, U.S. production of beryllium ore and total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide continued to decrease (table 1). Beryllium was used in applications such as computers, telecommunications, and automotive electronics.

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, continued to offer and sell selected beryllium materials from the national defense stockpile (NDS). The Generalized System of Preferences (GSP), a renewable preferential trade program, was extended to September 30, 2001. Most beryllium price quotations remained unchanged. Overall U.S. exports of beryllium were down and overall imports of beryllium were up in 2000 compared with those in 1999.

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, various materials have been purchased for the NDS. The stockpile goal, effective as of October 5, 1999, for beryllium metal was 45 metric tons (t), (table 2). For fiscal year (FY) 2000 (October 1, 1999, through September 30, 2000), the DNSC sold about 1,810 t of beryl ore valued at about $158,000; about 2,040 t of beryllium copper master alloy (BCMA) valued at about $12 million; and about 23 t of beryllium metal valued at about $4.15 million from the NDS. As of September 30, 2000, beryllium inventory sold but not shipped from the NDS included about 3,050 t of beryl ore; about 1,110 t of BCMA; and about 29 t of beryllium metal (U.S. Department of Defense, 2001, p. 13-14, 42, 47).

In its revised annual materials plan (AMP) for FY 2001 (October 1, 2000, through September 30, 2001) and proposed AMP for FY 2002 (October 1, 2001, through September 30, 2002), the DNSC had authority to sell about 3,630 t of beryl ore, about 2,000 t of BCMA, and about 36 t of beryllium metal (Defense National Stockpile Center, 2001a, b). The National Defense Authorization Act for FY 2000 (Public Law 106-65, October 5, 1999) authorizes the President of the United States to dispose of about 227 t of beryllium metal from the NDS. The President may not, however, dispose of the material to the extent that the disposal will result in "(1) undue disruption of the usual markets of producers, processors, and consumers of the materials proposed for disposal; or (2) avoidable loss to the United States" (U.S. Department of Defense, 2001, p. 31, 32). For FY 2001, through June 30, 2001, the DNSC sold about 1,260 t of BCMA valued at about $7.62 million and about 23 t of beryllium metal valued at about $3.62 million from the NDS.

Under the GSP, the United States grants duty-free access to eligible products from designated developing countries. In

Beryllium in the 20th Century

Beryllium was discovered in 1797 as a constituent of the mineral beryl. The metallic form was isolated in 1828 and named beryllium. It was not until 1926, however, that the true value of beryllium was realized. U.S. production of beryllium-copper alloys began in 1932, and in the 1940s, a commercial process was developed to produce beryllium metal. An early use for beryllium was in copper and nickel alloys, which were used in electrical components in machinery. In 1969, a beryllium mine opened in Utah that provided a large secure source of domestic raw material supply. Although statistics are not available for beryllium in the early years of its development, in 1940, U.S. mine shipments of beryllium ore (mostly from Colorado, Maine, and South Dakota) totaled about 110 metric tons valued at about $3,720. World production of beryllium ore was about 2,100 tons; Argentina was the major producer accounting for about 70% of the total. U.S. imports of beryllium ore totaled about 730 tons valued at about $24,000; Argentina and Brazil were the major sources.

In 2000, the United States was one of three countries that processed beryllium ores and concentrates into beryllium products. World beryllium ore production totaled about 6,000 tons; the United States, Russia, and Kazakhstan were the leading producers. Beryllium ore production in the United States was about 4,500 tons, mostly from Utah. Beryllium imports in the form of beryllium alloy and compounds totaled more than 150 tons valued at about $2.5 million. There were no imports of beryllium ore. U.S. beryllium consumption totaled about 300 tons of contained beryllium valued at about $110 million. The use of beryllium (as an alloy, metal, and oxide) in electronic and electrical components and aerospace and defense applications accounted for an estimated 80% of total U.S. consumption.

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2000, U.S. import duties for selected beryllium materials ranged from duty free to 8.5% ad valorem for normal-trade-relations (NTR) status and from duty free to 45% ad valorem for non-NTR status (U.S. International Trade Commission, 1999). In March, the GSP program, which expired on June 30, 1999, was renewed through September 30, 2001, retroactive to July 1, 1999, by a provision in the Ticket To Work and Work Incentives Improvement Act of 1999. The U.S. Customs Service began processing refunds due to the renewal on January 7, 2000 (U.S. Customs Service, 2000).

In December, the U.S. Department of Energy (DOE) published a notice of intent to establish the Worker Advocacy Committee. The Committee would provide DOE with advice, information, and recommendations on programs to assist workers diagnosed with work-related illnesses (including ongoing beryllium medical surveillance programs) in filing state workers' compensation claims. The Committee would "(1) provide advice to the Department of Energy on workers' compensation policy issues of concern to the Department; (2) periodically review worker advocacy program initiatives and recommendations; and, (3) provide advice on plans, priorities, and strategies to improve advocacy practices and procedures of the worker advocacy program." Committee members would be chosen from workers and union representatives, State and federal workers' compensation specialists, occupational physicians, medical and public health organizations, academic researchers, and the public at large (U.S. Department of Energy, 2000).

"The Energy Employees Occupational Illness Compensation Act of 2000, Public Law 106-398, establishes a program to provide compensation to individuals who developed illnesses as a result of their employment in nuclear weapons production-related activities and at certain federally-owned facilities in which radioactive materials were used." On December 7, 2000, the President issued Executive Order 13179 directing DOE to publish in the Federal Register (no later than January 15, 2001) a list of covered facilities. The list would cover three categories defined by the act—atomic weapons employer facilities, DOE employer facilities, and facilities owned and operated by a beryllium vendor. The initial list was published on January 17, 2001. The list was revised on June 11, 2001, and contained 43 beryllium-related facilities. The list indicated private firms that processed, produced, or provided beryllium metal for the DOE. The information was taken from a variety of historical documents, to the extent that DOE was able to identify and locate records, and the DOE welcomed comments and additional information about its beryllium vendors (Clinton, 2000; U.S. Department of Energy, 2001a, b).

Production

The U.S. Geological Survey collects beryllium data from two voluntary surveys of U.S. operations. In 2000, five respondents to the "Beryllium" and the "Mineral Concentrate and Beryllium Ore" surveys produced 100% of total domestic mine shipments presented in tables 1 and 7. A small number of unidentified producers may have shipped negligible quantities of byproduct beryl, which have not been included.

The United States, one of only three countries that process beryllium ores and concentrates into beryllium products, supplies most of the rest of the world with these products. Brush Wellman Inc., Cleveland, OH, mined bertrandite and converted ore of this mineral, along with imported beryl, into beryllium hydroxide at its operations near Delta, UT. Beryllium hydroxide was shipped to the company's plant in Elmore, OH, where it was converted into beryllium alloys, oxide, and metal. Brush Wellman also operated a plant in Reading, PA, that produced thin precision strips of beryllium-copper and other alloys and beryllium-copper rod and wire. About $2.4 million was spent on an annealing furnace to increase production capacity at the facility, with completion anticipated for the second half 2001 (Brush Engineered Materials Inc., 2001a, p. 3, 19, 2001b, p. 4).

In May 2000, Brush Wellman's shareholders approved the reorganization of its corporate and capital structure, and the company became a wholly owned subsidiary of Brush Engineered Materials Inc., a holding company headquartered in Cleveland, OH. Each share of Brush Wellman's common stock was exchanged for one share of Brush Engineered Materials' common stock. Brush Engineered Materials owned operations in Asia, the United States, and Western Europe and employed about 2,500 people. Company operations were organized into two business segments, the Metals Systems Group and the Microelectronics Group. The Metals Systems Group included Brush Wellman, the company's largest subsidiary, which produced strip and bulk products (mostly beryllium-containing alloys) and beryllium metal and beryllium-aluminum products (Brush Engineered Materials Inc., 2001a, p. 1, 7, 13-14, 18, 28, 33).

NGK Metals Corp., headquartered in Reading, PA, a subsidiary of NGK Insulators, Ltd. of Japan, produced beryllium alloy products at a plant in Sweetwater, TN. Because NGK Metals does not have facilities to process beryllium ores and concentrates, the company purchases beryllium oxide from Brush Wellman.

Environment

Because of the toxic nature of beryllium, the industry must maintain careful control over the quantity of beryllium dust and fumes in the workplace. The U.S. Environmental Protection Agency issues standards for certain hazardous air pollutants, including beryllium, under the Clean Air Act, and the Occupational Safety and Health Administration issues standards for airborne beryllium particles. To comply with these standards, plants are required to install and maintain pollution-control equipment. In beryllium-processing plants, harmful effects are prevented by maintaining clean workplaces; requiring the use of safety equipment, such as personal respirators; collecting dust, fumes, and mists at the source of deposition in dust collectors; establishing medical programs; and implementing other procedures to provide safe working conditions. Standards for exposure to beryllium were under review (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 278-280; Kramer, 1998, p. 107-108; Brush Engineered Materials Inc., 2001a, p. 6, 7, 19). Control of potential health hazards adds to the final cost of beryllium products.

Consumption

In 2000, domestic mine shipments and beryllium-containing ore consumption continued to trend downward. According to

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its annual report, Brush Engineered Materials' worldwide sales continued at a record pace, about $564 million in 2000 compared with about $456 million in 1999. Beryllium-containing products accounted for more than 50% of total company sales. The domestic market accounted for 73% of the company's revenue compared with 70% in 1999. Telecommunications (33%) was the leading revenue market. The Metal Systems Group (which included Brush Wellman's Alloy Products and Beryllium Products business units) had revenues of about $378 million, about 67% of total revenues. Alloy Products (primarily copper-beryllium alloys) sales increased to $270 million. Yield and equipment reliability issues at the Elmore plant, however, limited the company's ability to supply total product market demand. The alloys, sold in strip and bulk form, are used in applications such as computers, telecommunications, automotive electronics, oil and gas exploration, and undersea communications. Beryllium Products sales increased to $25 million, owing to increased second half year sales of beryllium aluminum alloy and beryllium metal products for defense related applications. Company international sales totaled about $150 million ($98.4 million from international operations, with facilities in England, Germany, Japan, and Singapore, and $51.2 million from U.S. operations' exports) compared with about $138 million in 1999 (Brush Engineered Materials Inc., 2001a, p. 2-3, 6, 13-14, 16; 2001b, p. 3).

During the year, Brush Wellman entered into a long-term supply arrangement with Kazatomprom National Atomic Co. and Ulba Metallurgical Plant Open Stock Co. in Kazakhstan and their marketing representative Nukem Inc. in New York for the supply of copper-beryllium master alloy and certain other beryllium-containing materials. Brush Wellman was to purchase the alloy and materials from Nukem, a wholly owned subsidiary of Tessag AG, Germany, which had a supply agreement with Ulba, a unit of Kazatomprom, who would produce the material. Annual purchase commitments for 2001 through 2009, totaled $5.8 million in 2001, $7.7 million in 2002, $9.7 million in 2003, $11.6 million in 2004, $13.5 million in 2005, and $15.4 million per year thereafter. Also, Brush Wellman was to purchase $3 million of beryllium ingot in 2001. The agreement could be terminated at any time with written notice for causes of action. The purchased material would be used by Brush Wellman in the manufacture of high-performance alloy products and would augment its U.S. beryllium sources (Brush Wellman Inc., 2000; Brush Engineered Materials Inc., 2001a, p. 22, 40).

U.S. apparent consumption of all beryllium materials was estimated to be about 300 t of contained beryllium in 2000 compared with about 385 t in 1999.

Beryllium-Copper Alloys.—Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications. These alloys are used because of their electrical and thermal conductivity, high strength and hardness, good corrosion and fatigue resistance, and nonmagnetic properties. Beryllium-copper strip is manufactured into springs, connectors, and switches for use in applications in automobiles, aerospace, radar and telecommunications, factory automation, computers, home appliances, and instrumentation and control systems. The principal use of large-diameter beryllium-copper tubing is in oil and gas drilling equipment and in bushings and bearings in aircraft landing gear and heavy machinery. Connectors in fiber-optic telecommunications systems are the main application for beryllium-copper rod. Small, pluggable sockets for joining integrated circuits to printed circuit boards are the main application for beryllium-copper wire. Beryllium-copper bar and plate are used in resistance-welding parts, components for machinery and materials-handling systems, and for molds to make metal, glass, and plastic components.

Beryllium also is used in small quantities in nickel- and aluminum-base alloys. Miniature electronic connector components that operate at high temperatures are the main use for beryllium-nickel alloys. These alloys also are used in automotive passive restraint systems (airbags). Beryllium-aluminum alloys are used as castings in the aerospace industry. The addition of small quantities of beryllium to magnesium alloys inhibits oxidation.

Beryllium Metal.—Beryllium metal is used principally in aerospace and defense applications. Its high level of stiffness, light weight, and dimensional stability within a wide temperature range make it useful in satellite and space vehicle structures, inertial guidance systems, military aircraft brakes, and space optical system components. Because beryllium is transparent to x rays, it is used in x-ray windows. In nuclear reactors, beryllium also serves as a canning material, as a neutron moderator, and in control rods. In the past, the metal had been used as a triggering device in nuclear warheads. Other applications for metallic beryllium include high-speed computer components, audio components, and mirrors. In the U.S. space shuttles, several structural parts and brake components use beryllium.

Beryllium Oxide.—Beryllium oxide (beryllia) is an excellent heat conductor, with high levels of hardness and strength. This material also acts as an electrical insulator in some applications. Beryllium oxide serves mainly as a substrate for high-density electronic circuits for high-speed computers, automotive ignition systems, lasers, and radar electronic countermeasure systems. Because it is transparent to microwaves, microwave communications systems and microwave ovens may use beryllium oxide.

Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. Graphite, steel, and titanium may be substituted for beryllium metal in some applications, and phosphor bronze may be substituted for beryllium-copper alloys, but these substitutions can result in substantial loss in performance. In some applications, aluminum nitride may be substituted for beryllium oxide.

Prices

Yearend price quotes for beryllium materials and products are shown in table 3. Published prices for most beryllium materials remained unchanged throughout the year, with the exception of beryllium metal and beryllium oxide. In June the price for 99% beryllium metal powder increased to $421 per pound, beryllium vacuum-cast ingot increased to $492 per pound, and beryllium oxide increased to $100 per pound. The American Metal Market published prices for other selected beryllium products were as follows: BCMA, $160 per pound of contained beryllium, unchanged since August 1987; beryllium-copper strip, $8.90 per pound, unchanged since January 1993; and

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beryllium-aluminum alloy, $260 per pound, unchanged since January 1995. The Metal Bulletin published price for beryl ore, which ranged from $75 to $80 per short ton unit of contained BeO, has remained the same since 1990.

Significant events affecting beryllium prices since 1958 include the following: 1969, bertrandite mine established in the United States providing a significant raw materials source; 1977, effects of inflation, increased energy costs, and additional costs associated with complying with air emission standards resulted in increased prices; 1979, beryllium metal price set by one producer; 1988, purchase of beryllium metal for the NDS; 1990, conversion of NDS beryl ore to beryllium metal for the NDS; and 1991, recession and dissolution of the U.S.S.R (Cunningham, 1999).

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall beryllium exports were down by about 14% compared with those of 1999. France, Germany, Japan, the Republic of Korea, the Netherlands, and the United Kingdom were the major recipients of the materials, with about 85% of the total. Overall beryllium imports increased by about 20%. BCMA imports were up by more than 40%, with Germany providing more than 70% of the imports. Metal imports were down by more than 10%, with China, Estonia, and the United Kingdom accounting for about 95% of the materials. There were no beryl ore imports in 2000. The schedule of tariffs applied during 2000 to U.S. imports of selected beryllium materials is found in the U.S. International Trade Commission's Publication 3249, 2000 Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 1999).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic beryllium production to meet U.S. demand. For 2000, net import reliance as a percent of apparent consumption was estimated to be about 37% compared with about 48% in 1999. In descending order, Estonia, Germany, and China were the major sources for U.S. beryllium imports, on the basis of contained beryllium, accounting for more than 80% of the total. Other sources of imports were Belgium, Russia, and the United Kingdom.

The U.S. Census Bureau does not separately identify all imports and exports of beryllium products. The Journal of Commerce Port Import/Export Reporting Service (PIERS) provides some data on materials that are transported by ship. According to PIERS, about 890 t, gross weight, of beryllium products (mostly beryllium-copper) was imported in 2000, primarily from Japan. Exports of beryllium products (mostly beryllium-copper) totaled more than 600 t, gross weight; Japan received most of this material.

World Review

Annual world beryl production capacity (metric tons, contained beryllium) is listed in table 6. Estimated world beryl production (metric tons, gross weight) is listed in table 7. In 2000, estimated world beryl production (including bertrandite ore) decreased by about 9% compared with that of 1999. The two major producers, Russia and the United States, accounted for about 97% of total production.

Japan.—In November 1999, NGK Insulators completed a 2-year investment program that increased beryllium-copper alloy capacity at its plant in Handa, near Nagoya, to about 350 metric tons per month (t/mo) from about 300 t/mo. NGK indicated that Japanese and Asian demand for beryllium-copper alloys in 1999 was about 3,500 t. In addition to regional sales, NGK shipped semifinished products from Handa to its subsidiaries in Germany and the United States for fabrication. In 2000, Japanese demand for beryllium-copper alloys increased to a record level of about 300 t/mo, owing to increased use in portable telephones and automotive electrical equipment (Roskill's Letter from Japan, 2000; Metal Bulletin, 2001).

Kazakhstan.—Kazatomprom, Kazakhstan's national nuclear concern, reportedly invested about $36 million to develop beryllium, tantalum, and uranium production. Projects conducted included the introduction of carbothermy technology and the production of beryllium bars at the Ulba Metallurgical Plant. Kazatomprom owns 90% of Ulba shares. Kazatomprom's contract to supply Brush Wellman with beryllium, and for the exchange of technology, was reported to be worth more than $120 million (see consumption section of this report) (Interfax International Ltd., 2000a, b).

Russia.—At yearend 1999, the Chita region made a decision to join a federal program named Libton for the creation of a scientific production center for rare metals, including beryllium, in the Trans-Baikal region. The Chita region and TVEL, a producer and supplier of nuclear fuel controlled by the Russian Ministry of Atomic Energy, signed an agreement on liaison with the Priargunsky Mining and Chemicals Production Association, a uranium producer controlled by TVEL, and the Zabaikalsky Mining and Beneficiation Plant, a rare metal producer. The Ministry was to finance the program and coordinate efforts by Priargunsky and Zabaikalsky to produce materials for the nuclear sector (Interfax International, Ltd., 2000c).

Outlook

Beryllium alloys, primarily beryllium-copper, are expected to remain the dominant form of consumption for beryllium. Beryllium demand should rise owing to increased usage of beryllium-copper in automotive electronics, computers, and portable telephones. Also, the newer beryllium-aluminum alloys are expected to gain in importance in terms of beryllium demand, with usage in applications such as aerospace and computers. The beryllium-aluminum alloys contain up to about 60% beryllium, compared with beryllium-copper alloys, most of which contain about 2% beryllium (American Metal Market, 2000; Harben, 2000, p. 13, 14; Mining Journal, 2000).

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. In 2000, the United States consumed about 240 t of beryllium contained in beryllium-bearing ores, compared with about 260 t in 1999. Brush Engineered Materials Inc. (2001a, p. 20) reported proven bertrandite reserves in Juab County, UT, of about 7 million metric tons at yearend 2000, with an average grade of 0.263% beryllium. This represents about 18,300 t of contained beryllium, compared with about 18,700 t in 1999. About 87% of the beryllium is recovered from the ore during the extraction process.

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References Cited

American Metal Market, 2000, Electronics demand sparks beryllium-copper market: American Metal Market, v. 108, no. 241, p. 1, 16.

Brush Engineered Materials Inc., 2001a, Annual report—2000: Cleveland, OH, Brush Engineered Materials Inc., 46 p.

———2001b, Form 10-K—Fiscal year 2000: Securities and Exchange Commission, 16 p.

Brush Wellman Inc., 2000, Brush Wellman Inc. secures long-term copper beryllium master alloy supply from Kazakhstan producer: Cleveland, OH, Brush Wellman Inc. news release, September 19, 1 p.

Clinton, W.J., 2000, Executive Order 13179—Providing compensation to America's nuclear weapons workers: Federal Register, v. 65, no. 238, December 11, p. 77487-77490.

Cunningham, L.D., 1999, Beryllium, *in* Plunkert, P.A., and Jones, T.S., comps., Metal prices in the United States through 1998: U.S. Geological Survey, p. 9-11.

Defense National Stockpile Center, 2001a, FY 2001 revised annual materials plan and FY 2002 annual materials plan sent to Congress: Fort Belvoir, VA, Defense National Stockpile Center news release, February 22, 4 p.

———2001b, Revised FY 2001 annual materials plan: Fort Belvoir, VA, Defense National Stockpile Center news release, April 9, 2 p.

Harben, P.W., 2000, Beryllium—Executive Commodity Reports: London, Financial Times Energy, 23 p.

Interfax International, 2000a, Kazatomprom increases beryllium capacity: Mining & Metals Report, v. 9, issue 37 (442), September 8-14, p. 12.

———2000b, Kazatomprom produced 13% more uranium in three quarters: Mining & Metals Report, v. 9, issue 46 (451), November 10-16, p. 15.

———2000c, TVEL completes mine construction at tantalum deposit: Mining & Metals Report, v. 9, issue 40 (445), September 29-October 5, p. 15, 16.

Kramer, D.A., 1998, Beryllium, *in* Metals and minerals: U.S. Geological Survey Minerals Yearbook 1996, v. I, p. 107-112.

Metal Bulletin, 2001, Beryllium copper producer struggles to meet demand: Metal Bulletin, no. 8555, March 5, p. 11.

Mining Journal, 2000, Beryllium: Mining Journal, Mining Annual Review 2000, p. 1-4.

Petkof, Benjamin, 1985, Beryllium, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 75-82.

Roskill's Letter from Japan, 2000, Copper-beryllium alloys—Japanese demand reaches a record level: Roskill's Letter from Japan, no. 291, November, p. 12.

Rossman, M.D., Preuss, O.P., and Powers, M.B., 1991, Beryllium—Biomedical and environmental aspects: Baltimore, MD, Williams & Wilkins, 319 p.

U.S. Customs Service, 2000, Renewal of the Generalized System of Preferences: Federal Register, v. 65, no. 42, March 2, p. 11367, 11368.

U.S. Department of Defense, 2001, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 1999 through September 2000: Washington, DC, U.S. Department of Defense, 54 p.

U.S. Department of Energy, 2000, Notice of intent to establish the worker advocacy advisory committee: Federal Register, v. 65, no. 239, December 12, p. 77604.

———2001a, Energy Employees Occupational Illness Compensation Act of 2000; list of covered facilities: Federal Register, v. 66, no. 11, January 17, p. 4003-4009.

———2001b, Energy Employees Occupational Illness Compensation Act of 2000; revision to list of covered facilities: Federal Register, v. 66, no. 112, June 11, p. 31218-31224.

U.S. International Trade Commission, 1999, Harmonized tariff schedule of the United States—2000: Washington, DC, U.S. Government Printing Office, U.S. International Trade Commission Publication 3249, variously paginated and unpaginated.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Beryllium. Ch. in Metal Prices in the United States Through 1998, 1999.
Beryllium. Ch. in Mineral Commodity Summaries, annual.
Beryllium. Ch. in Minerals Yearbook, annual.
Beryllium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Beryllium. Mineral Industry Surveys, annual.

Other

American Metal Market, daily.
Beryllium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Company annual reports.
Defense National Stockpile Center stockpile reports and news releases.
Federal Register, daily.
Interfax International Ltd.
Metal Bulletin (London), semiweekly and monthly.
Mining Journal (London), weekly.
Platt's Metals Week, weekly.
Roskill Information Services Ltd. (London; last reported on beryllium in 1989).
Roskill's Letter from Japan, monthly.
Ryan's Notes, weekly.

TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons, beryllium metal equivalent)

	1996	1997	1998	1999	2000
United States:					
Beryllium-containing ores:					
Mine shipments	211	231	243	200	180
Imports for consumption, beryl 1/	1	9	13	1	--
Consumption, reported	234	259	272	260	240
Yearend stocks	139	110	81	17	114
World production 1/	255	276	289	248	226

-- Zero.

1/ Based on a beryllium metal equivalent of 4% in beryl.

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TABLE 2
BERYLLIUM IN GOVERNMENT INVENTORIES
AS OF DECEMBER 31, 2000

(Metric tons, beryllium content)

Material	Stockpile goal 1/	Disposal authority	National defense stockpile inventory	
			Uncommitted	Committed
Beryllium ore	--	280	280	33
Beryllium-copper master alloy	--	81	81	44
Beryllium metal	45	277	322	29

-- Zero.
1/ Goal effective as of October 5, 1999.

Source: Defense National Stockpile Center.

TABLE 3
YEAREND BERYLLIUM PRICES, 2000

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore	per short ton unit of contained BeO	$75-$80
Beryllium vacuum-cast ingot, 98.5% pure, in lots up to 1,000 pounds		492
Beryllium metal powder, in 1,000- to 4,999-pound lots and 99% pure		421
Beryllium-copper master alloy	per pound of contained Be	160
Beryllium-copper casting alloy		5.52-6.30
Beryllium-copper in rod, bar, wire		9.85
Beryllium-copper in strip		8.90
Beryllium-aluminum alloy, in lots up to 100 pounds; 62% Be, 38% Al		260
Beryllium oxide powder, in 10,000-pound lots		100

Sources: American Metal Market, Brush Wellman Inc., Metal Bulletin, and Platt's Metals Week.

TABLE 4
U.S. EXPORTS OF BERYLLIUM ALLOYS, WROUGHT OR UNWROUGHT, AND
WASTE AND SCRAP, BY COUNTRY 1/ 2/

Country	1999		2000	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Canada	6,630	$190	1,670	$40
France	2,010	1,020	5,880	1,270
Germany	3,320	617	5,200	715
Israel	172	22	867	147
Japan	7,110	1,360	6,440	1,470
Korea, Republic of	68	57	3,260	82
Netherlands	3,760	220	4,860	226
United Kingdom	10,700	2,710	3,450	802
Other	5,830 r/	577 r/	2,290	654
Total	39,600	6,770	33,900	5,410

r/ Revised.
1/ Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM ORE, METAL, AND COMPOUNDS 1/

Material	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)
Beryl ore	20,400	$13	--	--
Beryllium-copper master alloy	103,000	1,530	149,000	$2,480
Beryllium oxide and hydroxide	1,020	14	4,790	31
Beryllium, unwrought and waste and scrap	11,900	1,060	10,400	753

-- Zero.
1/ Data are rounded to no more than three significant digits.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
ANNUAL WORLD BERYL PRODUCTION CAPACITY,
DECEMBER 31, 2000 1/

(Metric tons, beryllium content)

Continent and country	Capacity
North America, United States 2/	360
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa	3
Total	14
Asia, China	75
Europe:	
Kazakhstan	7
Portugal	3
Russia	70
Total	80
South America, Brazil	5
Grand total	534

1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Includes bertrandite ore.

TABLE 7
BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1996	1997	1998	1999	2000
Brazil	6 4/	7 4/	5 r/ 4/	11 r/	10
Kazakhstan	100	100	100	100	100
Madagascar 5/	11	28	30	30	30
Portugal	5	5	5	4	4
Russia	1,000	1,000	1,000	1,000	1,000
United States (mine shipments) 6/	5,260	5,770	6,080	5,070	4,510
Zambia 5/	-- r/	-- r/	-- r/	-- r/	--
Total	6,380 r/	6,910	7,220	6,220	5,650

r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through June 8, 2001.
3/ In addition to the countries listed, China produced beryl and Bolivia may also have produced beryl, but available information is inadequate for formulation of reliable estimates of production.
4/ Reported figure.
5/ Includes ornamental and industrial products.
6/ Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

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BISMUTH

By Robert D. Brown, Jr.

Domestic survey data and tables were prepared by Carolyn F. Crews, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

U.S. bismuth consumption increased 4% during 2000, compared with that of 1999. Consumption increased in all sectors: bismuth alloys, chemicals and pharmaceuticals, and metallurgical additives. In 2000, all primary bismuth consumed in the United States was imported. The only domestic refinery, in Nebraska, produced bismuth as a byproduct of lead refining until July 1997. The last stocks of bismuth held in the national defense stockpile (NDS) were sold that same year. The largest foreign producers of refined bismuth were Belgium, China, Mexico, and Peru.

Domestically, about 42% of bismuth was used in bismuth alloys, 40% in pharmaceuticals and chemicals, 16.5% as metallurgical additives, and 1.5% for other uses (table 2). Only a small amount of bismuth was obtained by recycling old scrap.

In recent years, several new uses for bismuth have been developed as nontoxic substitutes for lead in various applications. These included the use of bismuth in brass plumbing fixtures, ceramic glazes, crystalware, fishing sinkers, lubricating greases, pigments, and solders. Bismuth was a leading candidate for replacing lead in applications that have an environmental impact, such as shot used for waterfowl hunting. Another newly developed use was in galvanizing to improve drainage of galvanizing alloys. Poor drainage causes galvanizing alloy to accumulate in corners and angles as well as bridge small holes and thin channels, which requires extra cleaning of the workpiece. Lead additions improve the drainage properties of galvanizing alloys. Zinc-bismuth alloys have the same drainage properties as zinc-lead alloys without the toxicity of lead (Gagné, 2000).

In 2000, the average New York dealer price for bismuth decreased from $3.85 per pound to $3.70 per pound (table 1). This reversed increases in 1998 and 1999, but the average price was still the second highest in 5 years. The value of bismuth consumed domestically in 2000 was about $17.4 million, the same as for 1999.

Legislation and Government Programs

The Defense Logistics Agency, which administers the NDS, sold the final 85 metric tons (t) of bismuth in the stockpile on November 4, 1997.

The conversion to plumbing alloys that contain bismuth rather than lead is driven by the Safe Drinking Water Act Amendments of 1996 (Public Law 104-182). This law bans lead from all fixtures, fluxes, pipes, and solders used for the installation or repair of facilities providing water for human consumption after August 1998.

The U.S. Environmental Protection Agency announced new standards for dangerous levels of lead on painted indoor surfaces, in dust, and on bare soil where children play. These new standards will provide new and uniform benchmarks on which to base remedial action to be taken to safeguard the public from exposure to lead. The standards, which affect Federal agencies, and State, local, and tribal governments, could further the use of bismuth as a lead substitute (U.S. Environmental Protection Agency, 2000).

The Copper Development Association has changed the name of its alloys, introduced in 1995 as SeBiLOY (containing selenium and bismuth), to Envirobrass to highlight the significant environmental and health benefits of the alloys to manufacturers and consumers. Envirobrass I and II contain a mixture of bismuth and selenium substituted for lead in red

Bismuth in the 20th Century

In 1900, the United States produced 200 metric tons of bismuth ore, all mined in Colorado, primarily bismuth carbonate from Lake County. The ore averaged about 7% bismuth and had a value of about $9 per ton, based on bismuth content. The ore also contained gold and silver, increasing its price to $70 per ton. The world's supply and pricing of metallic bismuth were closely controlled by Johnson Matthey and Co., Ltd., of England and the Government of Saxony, which today is a State of Germany. Supply was much greater than demand. Imports of bismuth totaled 82 tons valued at $250,000. A small amount of bismuth was imported in medical preparations. The main use for bismuth was in the manufacture of low-melting-point alloys for electric fuses, safety plugs for steam boilers, solders, amalgams, and baths for steel tempering. Most of these alloys contained various combinations of lead, tin, and cadmium with bismuth. In 1906, the Betts process for refining lead bullion became the major source of bismuth; since then bismuth has been known as a byproduct metal.

In 2000, U.S. consumption of bismuth was more than 2,000 tons; bismuth alloy consumption was 890 tons, chemical and pharmaceutical uses accounted for 860 tons, and metallurgical additives plus other uses reached approximately 380 tons. New uses included replacement for lead associated with environment or public health concerns (such as in fishing sinkers, waterfowl shot, and plumbing fixtures), weather resistant paints, and hot dip galvanizing. Since 1997, when domestic production and national stockpile sales ended, the United States has been completely dependent on imports for primary bismuth; only a relatively small amount of bismuth is recycled in the country. The world's leaders in refinery production in 2000 were Belgium, China, Mexico, and Peru. Although a myriad of new uses increased world bismuth demand during the 20th century, adequate reserves indicated that supply would be sufficient for future needs.

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brasses used for water meters, valves, and plumbing fixtures. A new alloy, Envirobrass III, is a lead-free yellow brass for permanent mold casting (Payne, 2000).

The Danish Minister for Environment and Energy announced that the country would prohibit lead in several products where it can be replaced. The ban takes effect in 2001 and has the goal of reducing lead consumption by one-third in the next few years (Mining Journal, 2000a).

Production

ASARCO Inc., formerly the only U.S. producer of primary bismuth, ceased production on June 30, 1997. Some domestic firms continued to recover secondary bismuth from fusible alloy scrap in 2000, but secondary production data were not available. Secondary production was estimated to be no more than 5% of domestic supply during the year.

Consumption

Domestic bismuth consumption data are collected by the U.S. Geological Survey through a voluntary survey. Of the 40 firms that received the consumption survey in 2000, 70% responded. The respondents accounted for an estimated 75% of the bismuth consumption in the United States. The amount used by the nonrespondents was estimated on the basis of reports from prior years or information from other sources.

Bismuth consumption in 2000 was estimated to be 2,130 t, a 4% increase from that of 1999 (table 1). There were small or moderate increases in each sector: bismuth alloys, chemical and pharmaceutical uses, and metallurgical additives in 2000. Chemical uses, comprising most of the bismuth consumed in earlier years, accounted for less than one-half of the bismuth used domestically for the fourth successive year; in 2000, it was supplanted for the first time as the leading sector of consumption. The best known chemical use is that of bismuth subsalicylate, the active ingredient in over-the-counter stomach remedies. Other bismuth pharmaceuticals are used to treat burns, intestinal disorders, and stomach ulcers; veterinary applications are important as well. Bismuth nitrate is the initial material used for the production of most other bismuth compounds. Other bismuth chemical and compound uses include applications ranging from superconductors to some pearlescent pigments in cosmetics and paints.

Bismuth metal is used primarily as an alloy and metallurgical additive (table 2). One class of bismuth alloys comprises the fusible (low-melting-point) alloys—combinations of bismuth and other metals, such as cadmium, gallium, indium, lead, and tin. Applications for these alloys included fuel tank safety plugs, holders for lens grinding and other articles for machining or grinding, solders, and sprinkler triggering mechanisms. Also, the metal used to produce shot for waterfowl hunting is categorized as a bismuth alloy.

Bismuth is added in small amounts to aluminum, copper, and steel alloys to improve machinability. It is also added to malleable iron to prevent the formation of graphite flakes.

There remains considerable interest in using bismuth as a nontoxic substitute for lead in several applications. Bismuth oxide has been replacing lead oxide in the fire assaying of precious metals and in ceramic glazes, and bismuth replaces lead as well as steel in shotgun pellets. In fact, one area of steady increase since 1994 has been the use of bismuth alloy cartridges for waterfowl hunting; the alloy has been 97% bismuth and 3% tin.

Bismuth also has been the primary candidate of researchers seeking substitutes to replace lead in products that traditionally have contained lead, such as plumbing fixtures and solders. Alloys that use bismuth (often in combination with selenium) to replace lead in plumbing brasses are in regular production. This strategy appears to be a promising metallurgical approach to meeting more stringent tapwater standards in the United States. Although bismuth use in water meters in particular has increased, growth in bismuth consumption as a metallurgical additive remained somewhat sluggish in 2000.

There has been an effort to replace lead in other applications as well. For example, bismuth has been a substitute for the lead added to steel to provide greater machinability. A major domestic steel company began to use a bismuth-containing substitute for the leaded alloy nearly 20 years ago. Nevertheless, although bismuth has been successful in replacing lead in various applications, it has been challenged as a lead substitute by tungsten and tin (Cusack, 1999).

Prices

The domestic dealer price for commercially pure bismuth, published by Platt's Metals Week, averaged about $3.70 per pound in 2000, representing a 4% ($0.15) decrease after 4% and 3% increases in 1999 and 1998, respectively (table 1). The price was $4.30 per pound at the beginning of 2000, after fluctuating between $3.15 and $4.65 during 1999. The price fell steadily (except for one increase in March) for almost three quarters during 2000, falling to $3.23 per pound in September. Then it began a fairly rapid increase, reaching $4.00 per pound and holding there until the end of the year. In recent years, bismuth price has cycled between lows of around $3.00 per pound and highs of about $4.00 per pound (Mining Journal, 2000c); this remained true for the year 2000. A major underlying factor for the apparent $4.00 ceiling continued to be the large amount of bismuth normally available from China at lower prices (Mining Journal, 2000d). The long decline during most of the year was attributed to the resumption of supply from Mexico, and the rapid increase in the last quarter was attributed to a brief reduction of supplies from China (Ryans Notes, 2000).

Trade

Total bismuth imports increased significantly—15% by weight in 2000 (table 4). The large increase in the amount received from Mexico (86%) represents a return to normal; in 1999, bismuth production in Mexico was limited by pollution concerns.

Exports nearly doubled by weight and more than doubled by value in 2000 (table 3). The largest increases were to Germany, Mexico, and the United Kingdom.

World Review

World refinery production increased, easing concerns over supply and contributing to the downturn in prices (table 5). Production remained relatively low in Peru owing to continued use of high silver and gold concentrates in favor of high bismuth-bearing concentrates (Mining Journal, 2001).

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On February 28, 2000, the Mexican environmental authority lifted restrictions on production by Industrias Peñoles, S.A., that had been affected to decrease lead pollution. This returned nearly 600 t of metal to the world bismuth market (Metal Bulletin, 2000).

Usually, bismuth is recovered as a byproduct of lead or tungsten production. The world's only significant potential source where bismuth could be the principal product is the Tasna Mine in Bolivia, which was closed in 1985 and is now for sale (Doorn, 2000). Corriente Resources Inc. of Vancouver and the state mining corporation Corporación Minera de Bolivia had planned to reopen the mine, but low prices delayed the startup. Possible byproducts or coproducts available from Tasna include copper, gold, and tungsten (Mining Journal, 1999).

Bismuth is to be a major coproduct from the new NICO Mine of Fortune Minerals, Ltd., in Northwest Territories, Canada. The deposit also contains cobalt, copper, and gold (Fortune Minerals, 2000).

In Bolivia, the newly private Vinto tin smelter was reopened by Allied Deals Corp. of the United Kingdom. In addition to tin, the smelter has a capacity of 30 tons per year (t/yr) of bismuth (Mining Journal, 2000b).

A new smelting unit at the Hunan Shizhuyuan Non-Ferrous Metal Mine, China's largest bismuth producer, was expected to increase bismuth production from 350 t/yr to more than 400 t/yr (American Metal Market, 2000). Almost 500 t, however, was produced by yearend (Metal Bulletin, 2001).

Current Research and Technology

The use of bismuth oxide additions in electronic ceramics increased, especially in Japan. The additions enhance the electronic properties of ferrites and ceramic capacitors (Roskill's Letter from Japan, 2001).

In applications such as thermal fuses and soldering, bismuth alloy wires as small as 1 millimeter in diameter are needed. A unique process is used to produce these wires. In traditional ingot casting or cold mold continuous casting, solid metal makes contact with the mold over a considerable area. The resulting friction between mold and wire causes the solidification structure normally expected: a structure that is very brittle bismuth in spite of its softness. By using a heated mold at just above the solidification temperature of the alloy, the wire is not solid until it begins to exit the mold. This can result in extremely ductile wires, which are very useful in the applications mentioned (Soda and others, 2000).

More than 100,000 t of steel have been successfully galvanized using a new galvanizing-alloy-containing bismuth. This alloy is the conventional zinc-nickel alloy used for reactive steels with the addition of 1.8% tin and 0.5% bismuth without special processing adjustments. The higher fluidity and wetability of the new galvanizing alloy results in lower consumption of zinc, better surface appearance, less dross, and less finishing required after galvanizing. A bonus is that the bath is maintained about 100° C lower than the conventional bath, resulting in a 2% reduction in energy consumption. Traditionally, lead additions have been used in many plants to produce similar results as well as to obtain a large grain size in the coating. The new procedure, however, yields as good or better results with a lead-free process (Beguin and others, 2000). A new zinc-bismuth alloy can replace the equivalent leaded alloy with good resulting properties. There is greater fluidity and better drainage of zinc (Gagné, 2000). This alloy, without nickel, is used for ordinary steels.

Yellow bismuth vanadate is a major component of a yellow pigment blend for hot-melt road markings and paints. The resulting markings have very good heat resistance, do not fade, and meet applicable transportation regulations for color and reflectance. Traditional paints for this purpose use lead and hexavalent chromium pigments. Both of these are toxic to plants and animals. The new blend is lead- and chrome-free and thus is free from environmental regulation (Gooding and Delaney, 2000).

Outlook

The long-range outlook for bismuth indicates that demand will probably grow, especially in new applications and as the development of nontoxic bismuth substitutes for lead continues. The use of bismuth in plumbing fixtures and shot for ammunition is still increasing in the United States and in Europe. A partial ban on lead has been announced in Denmark. In Japan and elsewhere, however, the increase in substitution for lead has been slow because the applicable environmental regulations are less stringent (Roskill's Letter from Japan, 1999).

Bismuth is usually a byproduct of lead; a significant near term increase in supply, therefore, is unlikely, especially because total world production of lead will remain relatively stable with a large and increasing fraction of lead demand satisfied by recycling. Nevertheless, a global shortage of bismuth is not anticipated. Despite any increase in world demand, Chinese supplies can be expected to help keep the bismuth market stable (Mining Journal, 2001).

It appears that low prices, due to the nearly constant availability of Chinese bismuth or to the general deflationary trend for metals during the past decade, are the limiting factor to bismuth supply (Carnak, 1999). Usually, more bismuth appears in the market whenever prices increase.

References Cited

American Metal Market, 2000, China producer boosting bismuth: American Metal Market, v. 108, no. 136, July 17, p. 10.

Beguin, P., Bosschaerts, M., Dhaussy, D., Pankert, R., and Gilles, M., 2000, GALVECO—A solution for galvanizing reactive steel: Bulletin of the Bismuth Institute, no. 76, 4 p.

Carnak, Rachel, 1999, China not to blame for poor markets: Metal Bulletin, no. 8422, November 1, p. 7.

Cusack, Paul, 1999, New uses to boost tin consumption: Metal Bulletin Monthly, no. 344, August, p. 35.

Doorn, Robert van, 2000, Corriente Resources, Inc.—Will David Lowell do it again? *in* Exploration—Needed more than ever: Toronto, Loewen, Ondaatje, McCutcheon Ltd., January 11, p. 16.

Fortune Minerals, 2000, Fortune Minerals announces NICO drill results: London, Ontario, Canada, Fortune Minerals press release, October 5, 5 p.

Gagné, Martin, 2000, Hot dip ain't what it used to be: American Metal Market, Special Report, v. 108, no. 42, March 27, p. 9.

Gooding, K.D., and Delaney, J.M., 2000, Yellow pigment blend for hot melt traffic markings: U.S. Patent No. 6,036,764, March 12, 4 p.

Metal Bulletin, 2000, Environmental agency ends pollution restrictions at Peñoles: Metal Bulletin, no. 8455, March 2, p. 5.

———2001, Chinese bismuth mine resumes production: Metal Bulletin, no. 8540, January 11, p. 7.

Mining Journal, 1999, Minor metals in December: Mining Journal, v. 332, no. 9515, January 15, p. 27.

——— 2000a, Denmark to outlaw lead: Mining Journal, v. 335, no. 8611, December 1, p. 438.

———2000b, Minor metals in May: Mining Journal, v. 334, no. 8566, June 9, p. 453.

———2000c, Minor metals in September: Mining Journal, v. 335, no. 8603,

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October 6, p. 281.
——— 2000d, Minors march halted: Mining Journal, v. 334, no. 8577, April 7, p. 273.
———2001, Minor metals in January: Mining Journal, v. 336, no. 8619, February 2, p. 91.
Payne, R.M., 2000, US industry seen continuing record growth: American Metal Market, Special Report, v. 108, no. 32, February 17, p. 5A.
Roskill's Letter from Japan, 1999, Cadmium and bismuth—Impact of environmental issues: Roskill's Letter from Japan, no. 279, July, p. 6.
———2001, Strong domestic demand in electronic ceramics: Roskill's Letter from Japan, no. 293, January, p. 11.
Ryans Notes, 2000, Antimony takes a breather: Ryans Notes, v. 6, no. 38, September 18, p. 4.
Soda, H., McLean, A., Kadowaki, H., and Motoyasu, G., 2000, Flexible bismuth wires: Bulletin of the Bismuth Institute, no. 75, 4 p.
U.S. Environmental Protection Agency, 2000, EPA announces tough new standards for lead: Washington, DC, U.S. Environmental Protection Agency press release, December 26, 2 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Bismuth. Ch. in Mineral Commodity Summaries, annual.
Bismuth. Ch. in Minerals Yearbook, annual.
Bismuth. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Bismuth. Mineral Industry Surveys, quarterly.

Other

Bismuth. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT BISMUTH STATISTICS 1/

(Metric tons, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Consumption	1,520	1,530	1,990	2,050	2,130
Exports 2/	151	206	245	257	491
Imports for consumption	1,490	2,170	2,720	2,110	2,410
Price, average, domestic dealer, per pound	$3.65	$3.50	$3.60	$3.85	$3.70
Stocks, December 31, consumer	122	213	175	121	118
World:					
Mine production (metal content) 3/	3,600 r/	4,490 r/	3,990 r/	3,370 r/	3,760 e/
Refinery production 3/	4,180	4,070	4,040 r/	3,800 r/	4,370 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Comprises bismuth metal and the bismuth content of alloys and waste and scrap.
3/ Excludes the United States.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Chemicals 2/	855	861
Bismuth alloys	823	889
Metallurgical additives	340	346
Other	31	34
Total	2,050	2,130

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

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TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY 1/

Country	1999 Quantity (kilograms, metal content)	1999 Value (thousands)	2000 Quantity (kilograms, metal content)	2000 Value (thousands)
Australia	41	$9	--	--
Belgium	83,400	453	819	$13
Canada	87,700	732	84,900	806
Dominican Republic	1,240	67	2,570	140
France	--	--	87	9
Germany	19,000	168	151,000	1,910
Honduras	--	--	14,600	184
Hong Kong	7,900	100	912	109
Ireland	94	5	--	--
Japan	--	--	5	6
Korea, Republic of	--	--	33,700	59
Malaysia	919	3	5,930	58
Mexico	29,900	289	99,100	875
Netherland	--	--	21,100	61
New Zealand	50	5	--	--
Norway	--	--	20	6
Russia	--	--	4,750	60
Singapore	1,240	22	276	12
Taiwan	46	7	510	10
Trinidad and Tobago	15,900	46	13,100	74
United Kingdom	8,230	84	56,300	432
Venezuela	947	10	1,330	19
Total	257,000	2,000	491,000	4,840

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY 1/

Country	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)
Bahamas, The	735	$8	5,400	$11
Belgium	742,000	5,790	832,000	6,870
Canada	108,000	827	120,000	829
China	556,000	4,080	426,000	3,290
Finland	--	--	1	3
Germany	1,490	64	56,600	475
Italy	400	19	--	--
Japan	3,260	165	6,830	347
Korea, Republic of	--	--	14	4
Mexico	277,000	1,880	516,000	3,940
Netherlands	19,500	202	409	10
Peru	6,810	60	20,400	155
Spain	200	2	420	5
Switzerland	86	3	--	--
United Kingdom	391,000	2,220	430,000	3,180
Total	2,110,000	15,300	2,410,000	19,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	Mine					Refinery				
	1996	1997	1998	1999	2000 e/	1996	1997	1998	1999	2000 e/
Belgium e/	--	--	--	--	--	800	800	700	700	700
Bolivia	348 r/	684 r/	941 r/	709 r/ e/	740	28	55	44	57 r/	60
Bulgaria e/	40	40	40	40	40	40	40	40	40	40
Canada 3/	150	196 r/	219	311	202	--	--	--	--	--
China e/	610	550	240	400	400	750	760	820	1,300	1,300
Italy e/	--	--	--	--	--	5	5	5	5	5
Japan 4/	169 e/	165 e/	144 e/	135 e/	155	562	550	479	481 r/	518
Kazakhstan e/	115	115	115	130	130	50	50	50	55	55
Mexico 5/	1,070	1,642	1,204	548 r/	1,000	957	990	1,030	412 r/	900
Peru	1,000 e/	1,000 e/	1,000 e/	1,000 e/	1,000	939	774	832 r/	705 r/	744
Romania e/	40	40	40	40	40	35	35	35	35	35
Russia e/	50	50	35	50	50	10	10	7	10	10
Serbia and Montenegro e/	5	5	5	2	2	(6/)	(6/)	(6/)	(6/)	(6/)
Tajikistan e/	5	5	5	5	5	--	--	--	--	--
United States	W	W	W	W	W	W	W	--	--	--
Total	3,600 r/	4,490 r/	3,990 r/	3,370 r/	3,760	4,180	4,070	4,040 r/	3,800 r/	4,370

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 11, 2001. Bismuth is produced primarily as a byproduct of other metals, mostly lead; Bolivia is the sole producer of primary bismuth.

3/ Figures listed under mine output are the metal content of concentrates produced.

4/ Mine output figures have been estimated based on reported metal output figures.

5/ Refined metal includes Bi content of imported smelter products.

6/ Less than 500 kilograms. Production in kilograms: 1996--100 (estimated); 1997-2000--not available.

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BORON

By Phyllis A. Lyday

Domestic survey data and tables were prepared by Christopher H. Lindsay, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Boron produced domestically during 2000 totaled 546,000 metric tons (t) of boron oxide valued at $557 million (table 1). The most common minerals of commercial importance in the United States were colemanite, kernite, tincal, and ulexite (table 2). Boron compounds and minerals sold were produced by surface and underground mining, in situ, and from brine. U.S. consumption of minerals and compounds amounted to 360,000 t of boron oxide (table 3). Boron products are priced and sold based on the boron oxide content, which varies by ore and compound, and on the absence or presence of sodium and calcium (table 4). Boron exports totaled 532,000 t (table 5). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 6). The United States and Turkey were the world's largest producers of boron (table 7).

The glass industry, which remained the largest domestic market for boron production in 2000, accounted for 76% of boron consumption. Insulation-grade glass fibers accounted for an estimated 47% of domestic consumption; textile-grade glass fibers, 18%; boron sold to distributors, 9%; borosilicate glasses, 7%; soaps and detergents, 7%; enamels, frits, and glazes, 4%; and other uses, 8%.

Legislation and Government Programs

The U.S. Department of Energy (DOE) plans to store spent natural fuel encased in a boron-containing glass inside stainless steel containers underground at Yucca Mountain, NV, beginning in 2009. As a result of the DOE's delay in building a facility to accept spent nuclear fuel, PECO Energy Co. and the DOE had an agreement to reimburse costs incurred as a result of the delay. The DOE was required by law to begin accepting spent fuel by January 31, 1998 (Chemical & Engineering News, 2000a).

The U.S. Department of Justice, acting on behalf of the DOE, appealed to the district court in Las Vegas, NV, to overturn the Nevada State engineer's decision to deny water permits requested for the DOE's Yucca Mountain high-level nuclear waste project. In February, the Nevada State engineer denied the DOE's application to appropriate 530,000 cubic meters per year of water for use by the Yucca Mountain project beginning in 2002. These five permit applications for water rights were submitted by DOE in 1997 to perform activities mandated by the Nuclear Waste Policy Act (Mining Engineering, 2000a).

In 1990, the desert tortoise was listed by the Fish and Wildlife Service, U.S. Department of the Interior, as threatened. The tortoise is a major environmental issue in the Sonoran Desert, which extends from Utah to Mexico. The tortoise's habitat also includes boron areas being surface-mined and solution-mined. Since 1993, U.S. Borax Inc. has purchased and transferred more than 4,047 hectares (10,000 acres) of tortoise habitat to the Federal and State Governments at a cost of more than $5

Boron in the 20th Century

Production of borates began in California in 1864 in Lake County and in Death Valley and Armagosa Valley in 1882. In 1901, production was reported in California, Nevada, and Oregon as 16,227 metric tons of borax valued at $314,811 and 4,848 tons of refined borax valued at $697,307 for a total value of $1 million. Historical uses have included detergents, fire retardants, fluxes in glass and metals, and food preservatives. The major producing company was a California company, Pacific Coast Borax Company, which was consolidated under Borax Consolidated Ltd. (London) in 1903. In 1907, colemanite was mined in Inyo, Los Angeles, and Ventura Counties, CA. In 1914, the California borax company was liquidated, and a new Pacific Coast Borax Company was formed under Nevada law. Production from brine at Seales Lake, CA, began in 1919. Total production in 1920 was reported to be 109,153 tons valued at $2.2 million.

In 1927, large scale production of sodium borates began by Pacific Coast Borax from underground mines in Boron, CA. U.S. production in 1930 was 177,360 tons valued at $5.4 million. In 1956, the U.S. assets of Borax Consolidated were transferred to Pacific Coast Borax. In 1957, the existing three underground mines became one large surface mine. By 1960, U.S. production was reported to be 581,053 tons valued at $47.6 million, all from California.

In 1968, London-based RTZ Corp., the world's largest mining company and owner of Borax Consolidated and Pacific Coast Borax, merged with U.S. Borax. By 1970, U.S. production in California was 907,185 tons valued at $86.8 million from brines and underground and surface mines. American Borate Co., a wholly owned subsidiary of Owens-Corning, purchased the holding of Tenneco, Inc., in 1976, and development of the Billie Mine was completed in California in 1981. American Borate Co. was sold to a private firm in 1992. Mountain States Mineral Enterprises Inc. began an in situ pilot project near Newberry Spring, CA, which was sold to Fort Cady Minerals Corp., and production started at Fort Cady in 1995. Production at Searles Lake began in 1919 and continued into 2000.

In 2000, total borate production from four producers in California was reported to be 1.1 million metric tons valued at $557 million. Uses included glass (76%), sales to distributors (9%), soaps (7%), and other (8%).

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million. The company also created an endowment of nearly $240,000 for the California Department of Fish and Game to maintain and enhance the tortoise habitat (Rio Tinto Borax, 2001). During the past 10 years, as many as four tortoises each year are killed at Fort Irwin, CA, at the Army training center's grounds (Washington Times, 2000).

The Federal Railroad Administration of the U.S. Department of Transportation solicited proposals for the construction of a magnetic levitation (maglev) train to be built with funds approved by the Transportation Equity Act for the 21st Century. Maglev is an advanced transportation technology in which magnetic forces lift, propel, and guide a vehicle over a specially designed guide way. Boron is used in the superconducting and other high-intensity magnets in this system. By using state-of-the-art electric power and control systems, maglev would reduce the need for many mechanical parts, thereby minimizing resistance and permitting excellent acceleration and cruising speeds of about 386 kilometers per hour (240 miles per hour) or more. Since passage of the High-Speed Ground Transportation Act of 1965, a number of maglev system concepts had undergone research and development in the United States. The Federal Government had appropriated $1 billion to explore and construct a maglev segment of rail in various locations in the United States. The Federal Government declared the Pittsburgh and the Baltimore-Washington areas the finalists in a nationwide competition to build what could be the first commercial high-speed magnetic levitation train in the world (Federal Railroad Administration, January 18, 2001, U.S. Secretary of Transportation Slater selects two high speed maglev projects, accessed June 14, 2001, at URL http://www.fra.dot.gov/o/hsgt/hot.htm).

Production

Domestic data for boron were derived by the U.S. Geological Survey from a voluntary survey of U.S. operations. The majority of boron production continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA. Of the four operations to which a survey request was sent, all responded, representing 100% of the total boron produced (tables 1, 3).

More than 200 minerals contain boric oxide, but only a few were of commercial significance (table 2). Four minerals comprised almost 90% of the borates used by industry: the sodium borates borax and kernite, the calcium borate colemanite, and the sodium-calcium borate ulexite. These minerals were extracted primarily in California and Turkey and to a lesser extent in Argentina, Bolivia, Chile, China, and Peru.

American Borate Co. mined small amounts of colemanite and ulexite-probertite from the Billie Mine in Death Valley, CA. The ore was transported to Lathrop Well, NV, for processing. Storage and grinding facilities were at Dunn, CA. Reported employment was 110 employees (Business.com, [undated], American Borate Co., accessed June 12, 2001, via URL http://www.business.com).

Fort Cady Minerals Corp. used an in situ process near Hector, CA, to produce a product containing 48% boron oxide. Because it is chemically precipitated, this product has advantages in the consistency of its chemical composition, namely, high boron oxide content, low impurities, and a consistent physical size. The product contained 25% calcium oxide, 0.8% sulfur, 0.1% chloride, 0.08% iron, and less than 1 part per million arsenic. In situ extraction required that wells be drilled 427 meters (m) (1,400 feet) into the ore body. A solution of dilute sulfuric acid was injected into wells in the borate ore. The boron-enriched solution was pumped to the surface and then reacted with lime to precipitate a pure calcium borate product. The product was dried and packaged.

In 2000, IMC Global Inc. announced the opening of new corporate headquarters in Lake Forest, IL. IMC Chemicals, headquartered in Overland Park, KS, operated the Trona and the Westend plants at Searles Lake in San Bernardino County. IMC Chemicals produced refined sodium borate and boric acid as a coproduct of soda ash and sodium sulfate from the mineral-rich lake brines. A series of closed systems circulated brines in the upper unit salt layer of the lake to increase the borax grade to a theoretical 1.45%. The brine was processed at the Westend plant and circulated back to the upper salt layer. IMC Global continued to divest a controlling share of IMC Chemicals, and another group of investors were considering purchasing the Searles Valley facilities at yearend.

U.S. Borax Inc., which was a member of Rio Tinto Borax Group, mined borate ores at Boron, CA, by open pit methods and transported the ores to the surface via a conveyor. At Boron, reserves containing the minerals kernite and tincal were reportedly in excess of 100 million metric tons (Mt) (Baele, 2000). Production was reported to be 570,000 t during 2000 compared with 543,000 t in 1999 (Rio Tinto, 2000). The stripping ratio was more than 36:1, and the quality of stripped overburden was projected to reach 100 Mt in 2000. During 2000, it was necessary to remove a layer of overburden between 107 m and 198 m thick to access the ore. As the mine advanced to the east and southeast, that overburden layer was projected to gradually increase to 366 m in thickness. A 32 t groundslide on the north slope of the pit in 1999 was the initiative for construction of less steep benches, starting at the top of the existing 17 benches. The 91-m thick ore contains four zones. The upper layer is borax, overlaying three layers of borax and kernite (Garrett, 2000). Ore was processed into sodium borate or boric acid products in the refinery complex adjacent to the mine. An onsite plant also produced anhydrous sodium borate and boric oxide. Refinery products were shipped by railcar or truck to North American customers or to the U.S. Borax Wilmington, CA, facility at the port of Los Angeles for international distribution. California employees include 1,100 people working at the principal mine and refinery in Boron, a refinery and shipping terminal in Wilmington, the global headquarters in Valencia, and a trona mine at Owens Lake that supplies raw material to the Boron refinery (Rio Tinto Borax, 2001).

Cogeneration plants, which are part of the boron-processing facilities at Boron, produced 100 megawatts (MW) of electricity, 85 MW of which were sold to Southern California Edison. One-third of the electricity used at the site goes to operate pollution control equipment (Rio Tinto Borax, 2001). Another cost saving practice was a daily tire pressure check, which would increase tire life by 40%. An environmentally sound practice blended engine oil with diesel fuel to dispose oil and increase engine life by 20% (Garrett, 2000).

A new $10 million plant at Boron was projected to be able to process more than 1,400 metric tons per day of dry pond material containing 300,000 metric tons per year (t/yr) of high

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quality feed (25% boron oxide) for the sodium borate process. Before 1985, thickened clays and muds were sent to storage ponds along with plant liquid effluents containing low levels of borax. The clays contain low levels of pyrrhotite, a paramagnetic iron sulfide mineral, that is attracted to powerful rare-earth magnets (Mining Engineering, 2000b).

On May 1, 1999, U.S. Borax purchased the assets of Lake Minerals Corp., a trona mining operation on Owens Lake near Lone Pine in the central California mountains. Designated as U.S. Borax Inc., Owens Lake Operations, the facility would allow Borax to ensure control of its trona supply used in the borate refining process. Trona provided a cost-effective source of carbonates, which helped reduce scaling in the processing equipment. Owens Lake was the third largest trona deposit in the United States.

The 116-year-old Borax 20-mule team wagons were used in the 110th Tournament of Roses in Pasadena, CA, in 1999, and were placed on be permanent display at the Borax visitors center on the edge of the Boron Mine. The visitors center had been open 7 days a week since October 1997, marking the company's 125 anniversary of doing business in California. It was set up as an educational center for modern mining and the impact on minerals on daily life (U.S. Borax Inc., December 21, 1998, Twenty-mule team takes its final ride, accessed October 17, 2000, at URL http://www.borax.com/nonflashsite/company/news_20mule.html). The founder of the 20-mule team, Francis Marion "Borax" Smith, was buried in Mountain View Cemetery, Oakland, CA, in "Millionaire's Row" (Find a Grave, [undated], Frances Marion Smith "Borax", accessed April 7, 2000, at URL http://www.findagrave.com/pictures/3258.html).

The 849 employees at the Boron Mine processed about 3 million metric tons per year (Mt/yr) of ore (Rio Tinto Borax, 2001). Two new safety programs were instituted. A safety management audit training program trained employees to observe work practices and encouraged feedback. It transitioned from top-down model enforcement to bottom-up participation. A second program installed video cameras on the trucks to eliminate drivers' blind spots. The primary goal was to improve safety (Craig, 2000).

The Gerstley Borate Mine near Boron, CA, was closed because of the cost of meeting regulatory requirements, including fireproofing and replacing support timber. The run-of-mine ore was used in glazes as a secondary flux at midrange temperatures and a primary glaze at low temperature firing. The ore was popular in middle temperature glazes because its high melt fluidity produced a textured and variegated visual effect. The Gerstley ore was an aggregate of colemanite, ulexite, and hectorite. It also contained some limestone. Gerstley was named after a former president of the company (Gerstleyborate.com, [undated], What was Gerstley borate?, accessed May 24, 2001, at URL http://digitalfire.com/gerstleyborate/description.shtml).

Consumption

Total annual world consumption of borates was as follows: insulation, fiberglass, textile fieberglass, and heat-resistant glass (41%); ceramic and enamel frits and glazes (13%); detergents, soaps, and personal car products (12%); and agricultural micronutrients (6%).

Borate applications for glass consumption included the following five categories: borosilicate glass, ceramic frits and glazes, glass fiber insulation, porcelain enamels for steel and aluminum, and textile glass fiber. These five categories of glass have significantly different thermal, chemical, and mechanical properties, although their compositions contain chemicals drawn from the same list of about 10 oxides. Boron oxide allows the formulated glass to have high chemical durability, low thermal expansion, and low electrical conductivity. By using a computer simulation model, it is possible to predict glass properties from the oxide composition. Using models can lessen laboratory research time spent in product development by calculating new glass compositions that have the desired properties (Cook, 2000).

Glass fiber thermal insulation, primarily used in new construction, was a large area of demand for borates and was the principal insulating material used in the construction industry. Composed of very thin fibers spun from molten glass, fiberglass traps and holds air. Typically, between 4% and 5% of boron oxide is incorporated in its formulation to aid melting, to inhibit devitrification, and to improve the aqueous durability of the finished product.

Borates also were used in a range of products made from high-tensile-strength glass fiber materials. The process of producing glass fiber uses a borosilicate (e-glass) formulation that is continuously drawn through platinum alloy bushings into continuous 9-micrometer (μm) to 20-μm diameter filaments. Calcium aluminoborosilicate, e-glass, or textile fiberglass typically contains between 6% and 10% boron oxide.

The minerals colemanite and ulexite were used mainly for the production of ceramic frit on glazed tile, fiberglass, and glass wool. Because of variability of minerals, they must be milled to a fine particle size (200 mesh) and blended prior to use. The fineness of the grind eliminates coarse particles of quartz that could remain undissolved in the glass. Colemanite products were usually 75% to 85% pure and contained gangue in the associated minerals calcite, clays, and gypsum, and minerals that contain the elements aluminum, arsenic, iron, magnesium, silicon, strontium, and sulfur. Contained water in boron minerals can cause higher energy usage, increase stack emissions, decrease glass quality, and lower production rates. The water in calcium borate minerals is expelled at around 400° C accompanied by vigorous decrepitation of the ore, which can contribute to dust, causing greater refractory corrosion rates and increased particle emissions (Carr, 2000).

Slag is the waste steelmaking produces when unwanted impurities, such as silica, phosphorus, and manganese, are removed from the iron ore. A specialized borate was added to slag to allow the slag to cool slowly and prevent dust and mud. The fist-sized slag rocks formed were suitable for construction material (Borax Pioneer, 2000b).

Triphenylboron (TPB) and triisopropyl borate (TIPB) have been used by E.I. du Pont de Nemours and Co. (DuPont) to make nylon 6,6. For this process, adiponitrile is converted into hexamethylenediamine (HMD). HMD and adipic acid are the building blocks of nylon 6,6. The boron chemicals promote higher yields, but unlike catalysts, they are not reused, nor are they incorporated in the final product. Instead, they are hydrolyzed into boric acid before leaving the plant. The chemicals can be used as an agrochemical, catalyst, flame retardant, and fuel additive. DuPont would also be willing to

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sell the boron chemicals for use in nylon intermediates manufacturing in an arrangement under which DuPont would license the adiponitrile technology and supply TPB and TIPB (Tullo, 2001b).

Boric acid was used in wallboard, also known as drywall or gypsum board or plasterboard, to increase the production line speeds, to save raw material, to reduce energy and shipping costs, and to improve the overall board quality. No new wallboard plant had been constructed in North America in the past 10 years. With the rise in residential and commercial building in North America, there was increased demand for wallboard.

Boron is 1 of 16 nutrients essential to all plants. Boron is essential to plant growth and can be applied as a spray and incorporated in fertilizer, herbicides, and irrigation water. Boron applied in May and June can be combined with calcium. For early season apples, boron can be applied post-harvest to provide adequate nutrition as buds begin to develop. During 2000, 18,628 t of boron micronutrients were applied on crops compared with 20,398 t in 1999. The largest region of use was in the west north-central, which used 8,297 t (Terry and Kirby, 2001).

In solution, borates form negative ions that can link with certain organic substances containing alcohol groups. This is an important role of boron in regulating metabolism. Too much borate concentration will turn the regulation into inhibition and stop cells from growing. Stopping cell growth rather than killing the cell makes borate a biostat rather than a biocide. It explains how and why borate compounds can be use to control so many different pests and why acquired resistance to borates is unlikely. The mild biostatic effect also makes borates not harmful to humans. Natural borate compounds have been shown to work against and to control algae, bacteria, fungi, and many insects like ants, beetles, cockroaches, fleas, flies, moths, termites, and wasps. Examples of widespread commercial use of the bacteriostatic properties of borates include additives in air conditioning systems, caviar, cooling fluids, cooling water, cosmetics, eye drops, in-can preservatives for paints, and metal lubrication (Lloyd, 2000).

Advanced Ceramics Corp. opened a $30 million world headquarters in Strongsville, OH, on February 29. The transfer of equipment and people was scheduled to be completed by the end of 2003. The company produced boron nitride and other nonoxide advanced ceramic powders, hot-pressed shapes, and chemical vapor deposition shapes and coatings (Advanced Materials & Processes, 2000).

U.S. Borax teamed with Osmose Inc., which was the leading chemical supplier to the wood preservation industry, and L-P Corp., which was the world's largest producer of oriented strand board. Osmose would provide borate-treated lumber through its many licenses, and L-P Corp. would incorporate borates into some structural panel products. U.S. Borax would supply Timbor® Industrial (disodium octaborate tetrahydrate) for lumber and plywood, and Composibor® (zinc borate) for engineered wood products (Bhatia, 2001).

Transportation

In 2000, U.S. Borax products from the mine were transported primarily by rail, although trucks were also used. The company ranked as the primary bulk shipper in California on the Burlington Northern Santa Fe Railroad, which had a fleet of more than 700 rail cars. Ocean transport was from the port of Wilmington, CA, where it had the only remaining privately owned berth in the harbor. It ranked as the largest exporter of high-value dry bulk products and among the top 10 shippers of ocean containers out of the ports of Los Angeles and Long Beach, CA. About 10 ships per year, with a capacity of 40,000 deadweight tons each, were loaded for locations around the world.

Antwerp, Belgium, which had the most central port location in Europe, had access to 188 major European cities. The industrial minerals market in Europe was characterized by high volumes of imported materials, mostly forwarded through the industrialized areas of Belgium, France, Germany, and the Netherlands for destinations in Central Europe, such as Austria, the Czech Republic, and Slovenia. The decision to import material was based on the geographic location, the range of service needed, and prices.

U.S. Borax used barges to ship borates from Rotterdam in the Netherlands to customers in Belgium, Eastern Europe, France, Germany, and countries even farther away. For small consignments, trucks can be more competitive than barges. Barges were the most efficient and reliable method of transporting goods in Europe, which had a 25,000-kilometer (km) network of navigable canals and rivers. Most of the large industrial areas could be reached by barge on waterways linking parts of the North, the Baltic, the Black, and the Mediterranean Seas and the Atlantic Ocean. In 1992, the 170-km canal linking the River Main to the Danube was opened in Germany.

The Trona Railway connects to the Southern Pacific Railroad between Trona and Searles Stations.

Prices

Prices of boron minerals and compounds produced in Argentina, Brazil, Turkey, and the United States are listed in table 4.

World Review

Argentina.—Borax Argentina S.A., which was a subsidiary of Rio Tinto plc., was the country's leading producer of borates (table 6). Borax Argentina mined borates at three deposits in Salta and Jujuy Provinces. Tincalayu Mine, originally developed in 1976, was Argentina's largest open pit operation and measured 1.5 km long, 800 m wide, and 100 m deep. The clay overburden averages 50 m and typically overlies 30 to 40 m of ore. Ore was trucked from the mine to a rail terminal at Pocitos, 120 km north of Tincalayu, and loaded on trains of 11 cars, each with a 30 t capacity. The Quijano plant was ISO 9002 certified. Consumption of boron products was in agriculture, glass, fiberglass, frits, and other applications (Baele, 2000)

The newest producer was Procesadora de Boratos Argeninos S.A., owned by Ferro Corp. and Canadian JEM Resources & Engineering, Inc. The project was purchased in 1999 from S.R. Minerals Ltd., which was an affiliate of Smokey River Coal Ltd., a Canadian coal producer. Tincal and ulexite mined at Loma Blanca were processed with magnetic separation and then calcining at Palpalá. A range of calcined and noncalcined products were produced containing 35% to 60% boron oxide.

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Production was about 3,000 metric tons per month (O'Driscoll, 2001).

Norquímica S.A. was one of the few surviving boric acid manufacturers in Argentina. Ulexite was raked on the surface of the salars in Salta Province, spread out to dry, and trucked to the company's plant in Salta for concentrating. A portion of the ulexite concentrate is used as feed for the boric acid plant, where it is reacted with sulfuric acid.

Asia.—Albemarle was planning to offer zinc borate flame- and smoke-suppressing products in Asia under a commercial agreement with Borax Polymer Additive Group. The new zinc borate products broaden the company's range of halogen and halogen-free flame retardant systems. Albemarle's flame retardants fall under the umbrella of its polymer chemicals division, which generates about $450 million per year in sales (Chemical Market Reporter, 2000).

Bolivia.—Borate production was from companies that mined ulexite from Government concessions around Salar de Uyuni in the Bolivian Altiplano. Cia. Minera Tierra S.A. had large ulexite concessions near the Chilean border and produced dried and washed grades for export. Reserves were in the order of 5.5 Mt of boron oxide. In addition to ulexite, Tierra produced boric acid and in 1999 exported 12,500 t worldwide. The operation employed 250 in Bolivia and 45 in Chile.

On August 28, Bolivian (FELCN), Chilean (OS7), and U.S. (DEA) antidrug authorities descended on Tierra and its Chilean sulfuric acid supplier, Alco Ltda. Thirteen executive staff and employees were arrested. In December, the Bolivian executives were released, but the seven Chilean employees were detained. The charge was based on 7,000 to 15,000 t of sulfuric acid allegedly being deviated from the production of boric acid to the illegal cocaine processing plants in the Chapare district of Bolivia. The volume of sulfuric acid in question represented about 35% of Tierra's consumption in the production of boric acid. Judgement on the case in Bolivia was expected to begin in March 2001 (O'Driscoll, 2001).

The case, the first of its kind, highlighted potential problems that could arise with industrial minerals companies that need to consume or process predetermined "precursors," such as soda ash or sulfuric acid. These commodities were recognized by antidrug agencies as being the same level as "controlled substances" in narcotics culture (O'Driscoll, 2001).

The Pampa borax deposit, which was owned by Champagne Miner Rio Grande S.A., had ulexite ore with a boron oxide content of between 30% and 34% and 1.7 Mt of proven reserves. The deposit included 9 concessions comprising 4,480 mining claims and was located in Nor Lapis Province, south of the Salar de Uyuni.

Chile.—Borax Argentina, S.A., had 198 employees working at the Tincalayu, the Sijes, and the Porvenir Mines and the Campo Quijano refinery. The mine at Tincalayu, Salta, is Argentina's largest open pit mine, measuring 1,500 m wide, 500 m long, and 100 m deep. The main minerals mined are tincal, ulexite, colemanite, hydroboracite, and kernite. The mine operates at a rate of 100,000 t/yr. Energy is supplied by two generation plants, which produce 146,000 kilowatts per month (Rio Tinto Borax, 2001).

Quimica e Industrial del Borax Ltda. (Quiborax) mined ulexite from Salar de Surire, which was the largest ulexite deposit in the world. Reserves were estimated to be 1,500 t. The deposit was located at an altitude of 4,250 m in Monumento Natural de Surire, a national park. Production in 2000 was 380,000 t of crude ulexite. The ore was trucked to the El Aguila production facility north of Arica. Some of the ulexite was dried and sold, and the balance was reacted with sulfuric acid to produce 36,000 t of 98% to 99.9% boric acid. The majority of production was exported through the port of Arica.

Quiborax's other plants included a new granulated ulexite plant, which produced agricultural ulexite ranging between 10% to 13% boron oxide, and another special ulexite plant, which produced different types of boron ranging product between 30% to 45% boron oxide for specific market requirements (O'Driscoll, 2001).

Champagne Minera Salar de Atacama was 100% owned by Sociedad Quimica y Minera de Chile S.A. (SQM). A large integrated facility was scheduled to begin production of 16,000 t/yr of boric acid as a byproduct of potassium sulfate production. SQM was reported to be purchasing boric acid for resale until the plant could begin boric acid production. SQM also produced ulexite from reserves in excess of 7 Mt boron oxide content at Salar de Ascotán and Salar de Carcote (O'Driscoll, 2001).

China.—Over 80% of the country's borates resources were in Liaoning and Jilin Provinces. The ores were primarily metamorphic deposits containing primarily ascharite, a magnesium borate. Other production was from playa lakes in Qinghai, where borate minerals, such as ulexite, hydroboracite, and borax, were produced from brines near the Qinghai-Tibet plateau (O'Driscoll, 2001).

China announced Shangha's plans to be the world's first city to build a commercial maglev train (Denver Post Newspaper in Education, 2001, Magnetic levitation train, accessed March 22, 2000, at URL http://www.colokids.com/indexd4.htm).

India.—Submarginal borax reserves occur in the Puga Valley Districts of Jammu and Kashmir. In Rajasthan State, the bitterns from Lake Sambhar were reported to contain about 0.5% borax.

Italy.—Rio Tinto Borax appointed Milan-based Novaria Chemicals as its exclusive distributor of its Firebrake range of fire retardant polymer additives in the Italian market. Novaria provided expertise in the storage, handling, and distribution of plastic additives (Chemical Market Reporter, 2001).

Kazakhstan.—More than 100 boron deposits have been discovered in northern Prekaspiy. Boron deposits of the Inder groups were concentrated in the gypsum of salt domes and salt rock masses. Borates associated with gypsum include ascharite (szaibelyite), hydroboracite, inyoite, and ulexite. At two sites, dredging by means of drag lines took place at a depth of 15 to 20 m below water level. Borate ore reserves were reportedly estimated to be 2 Mt, but the undiscovered resources could reach 120 Mt of 9% boron oxide.

Peru.—Inkabor S.A., owned by the Italian Colorobbia Group, mined ulexite at Laguna Salinas, which is 80 km east of Arequipa. The open pit operation produced from 150,000 to 180,000 t/yr of ulexite ore during 6 or 7 months of mining. Large stocks were maintained for sales during the winter season. The crude ulexite was washed to produce a concentrate. The calcining plant operated 24 hours per day to produce calcined ulexite in granular and powdered forms. Ulexite was supplied to Oquendo for boric acid production. Oquendo's plant in Arequipa had the capacity to produce 12,000 t/yr of boric acid and 15,000 t/yr of concentrated ulexite.

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Russia.—In August, 1999, Russia's sole borates producer, JSC Bor, was reorganized and renamed JSC Energomash-Bor in response to a move by Russian power equipment supplier JSC Energomash to become more involved in the borates business. In mid-2000, Energomash-Bor was preparing its second boric acid production line for commissioning, following a 9 month closure. The company also tested a nitrate method of processing datolite ore, which may permit a savings in power consumption. The refurbished plant was expected to double boric acid production and increase output of other boron products to between 100,000 to 140,000 t/yr (O'Driscoll, 2001).

Serbia and Montenegro.—Ras-Borati Ltd. began drilling the Piskanja boron deposit in the Jarandol Basin located near Baljevac in southern Serbia. Ras-Borati, which was established in February 1997, was a 50-50 joint venture between Erin Ventures Inc. of Kelowna, Canada, and Electroprivreda, the national power company of Serbia. A drilling program was planned to raise the status of a 7-Mt block of reserves that graded 35% to 39% ore from indicated to proven. The minerals were primarily colemanite and ulexite. Ras-Borati also held rights in the Pobrdjski Potok borate deposit in the Jarandol Basin. Proven and probable reserves of 140,000 t of ore reportedly averaged 37% boron oxide.

Tajikistan.—A skarn borosilicate deposit at Ak-Arkhar, which was situated at an elevation of 4,400 to 5,000 m, reportedly had measured and indicated reserves of danburite ore that exceed 80 Mt.

Turkey.—Turkey's boron operations were under the control of Eti Holding AS, formerly Etibank, through its subsidiary Eti Boron Inc. Co. Boron production was managed by five operations, four of which were integrated mine and plant facilities and one, at Bandirman port, was a plant facility. Additional capacity was planned for startup in 2002 with a 160,000-t/yr plant for borax pentahydrate at Kirka and in 2003 with a 100,000-t/yr boric acid facility at Emet (O'Driscoll, 2001).

United Kingdom.—Rio Tinto Borax, a wholly owned subsidiary of Rio Tinto, was dedicated to the mining, refining, and marketing of borates. Borax produced more than 1 Mt/yr of product from ore bodies in the United States and Argentina, employing 1,700 people worldwide. As a miner and refiner, Borax managed the environmental, social, and economic impact of its operations, applying the same standards at each location. These activities were classified under the headings of safety and stewardship. Borax believed its contribution to sustainable development to be that its operations have low environmental impact and make a positive social contribution, that its borate products enhance standards of living and contribute to economic development, and that borates measure up favorably in terms to most substitute products. To aid the mining industry in achieving sustainable development, the Industrial Minerals Association was formed as an industry association. In addition, a number of the world's largest mining companies established the Global Mining Initiative as a case for mining as a positive factor towards sustainable development. This was projected to lead to a major conference on mining and sustainable development in 2001 (Edbrooke, 2000; Mining Minerals Sustainable Development Project, [undated], Stainable development raises as many questions as it answers, accessed June 12, 2001, at URL http://www.globalmining.com/index.asp).

Borax Europe Ltd., a subsidiary of Rio Tinto Borax, was involved in a court case against one of its former employees over an alleged breach of confidentiality. The case involved a graph that was placed on the private website of the former employee. The company claimed that the graph disclosed information that was confidential to the company. At the August hearing, the employee voluntary agreed not to disclose any confidential information and to return the material used to Borax (Industrial Minerals, 2001).

Uzbekistan.—An oil and gas condensate deposit at Dzhartchi had the potential to produce 377 t/yr of boron oxide at a pumping rate of 4,000 cubic meters per day for more than 20 years.

Current Research and Technology

Millennium Cell plc of Eatontown, NJ, is developing a chemical storage technology based on sodium borohydride. A clear aqueous solution of about 30% sodium borohydride is exposed to a proprietary catalyst to yield hydrogen and sodium borate byproducts, resulting in a milky solution of spent fuel. Millennium is forming a joint development with Rohm and Haas Co., a major sodium borohydride supplier, to come up with a better process by closing the loop in the stream and recycling the sodium borate back to sodium borohydride. Millennium stated its storage density rivals liquid hydrogen at about 63 grams per liter (Tullo, 2001a).

A graduate student in chemical engineering at several universities has designed copolymers that can be applied to cells or tissues to prevent adhesion of antibodies or to block the body's response to its own tissues during wound healing. These copolymers could be used to coat organs prior to transplantation to prevent rejection. The backbone of these copolymers is a poly (l-lysine), and grafted onto the backbone are phenylboronic acid and poly ethylene glycol (Rouhi, 2000).

Sodium perborate bleaches stains extremely well at above 60° C temperatures as hydrogen peroxide releases oxygen into the wash. At temperatures of about 40° C, such activators as tetraacetylethylenediamine and nanayoyloxybenzenesulfonate can be used to release peracids that are effective oxygen sources. A new catalyst can release oxygen below 40° C that works like a biological enzyme, while suppressing any unwanted chemical reactions (Borax Pioneer, 2000a).

Albemarle Corp. and Borax Flame Retardant Group reached an agreement to develop joint applications for zinc borate in flame retardants. The goal is to increase the availability of halogen and halogen-free flame retardants to the polymer industry. Zinc borates are currently used in epoxy, plyamide, and polyvinylchloride compounds, but there are potential opportunities in engineering plastics, styrenics, and other resins (Industrial Minerals, 2000).

Boron-bearing antioxidants used in refractory bricks increase the resistance of the brick to oxidation and slag corrosion. The best results were achieved with combinations of aluminum boride with boron carbide and calcium boride when compared with zirconium boride additives (Hunold, 2000).

Colemanite and borax are the least and most soluble boron minerals of commercial importance, respectively. Boron minerals, such as colemanite and borax, which use primary amine collectors exhibit collector precipitation above a critical pH, determined by amine content. The collector precipitation

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was attributed to the formation of amine hydroborate. Studies indicate that the precipitate is dodecylamine and may enhance the floatability of colemanite (Akin and others, 2000).

A new family of weakly coordinating anions could greatly improve the activity of metallogen catalysts used in industrial olefin polymerizations according to researchers at Dow Chemical Co. Aluminum or boron is used in the anions (Chemical & Engineering News, 2000d).

Scientists at Osaka University, Japan, have developed a new catalytic reaction that adds multiple alkyl groups to aromatic rings using a norbornyl group on the phenyl ring. The process repeats itself, proceeding around the ring until steric factors interfere. The reaction of pheylboronic acid and 2-norborene in the presence of a rhodium catalyst yield primarily the tetranorbornylbenzene ring. The method provides a method for the synthesis of a unique class of sterically encumbered aromatic molecules (Chemical & Engineering News, 2000c).

Chemists at Emory University, Atlanta, GA, discovered a palladium-catalyzed coupling of thiol esters with boronic acids to produce ketones under mild conditions. Because the reaction proceeds even at a pH of 4.5, the conditions are very mild and will tolerate functional groups that would not survive standard cross-coupling systems. The reaction is mechanistically distinct from other processes where a base is normally used. The coupling of boronic acids to thiol esters expands boronic acid coupling into completely new fields (Zurer, 2000).

Chemists at the University of California, Irvine, CA, copolymerized two olefin monomers into an ethylene-polylene copolymer. Dimethylsulfoxomium methylide can be polymerized by triethylborane to make linear polymethylene, more commonly known as polyethylene. The research opens the door to designer polymers not obtainable through conventional polymerization of olefin monomers (Chemical & Engineering News, 2000e).

A new superacid powerful enough to protonate C_{60} to give HC_{60}^{+} as a stable ion in both solution and solid state was developed by the University of California, Riverside, CA. The superacid is based on the hexahalocarborane anion $[H(CB_{11}H_6X_6)]$, where X = Cl or Br. The new superacid and oxidant may allow the investigation of processes and reactive species previously difficult or impossible to study (Chemical & Engineering News, 2000b).

Physicists at Aoyama-Gakuin University, Japan, announced that magnesium diboride became superconductive when cooled to or below 39 K. This range of superconductivity is 16 K higher than any other simple metallic compound. The possibility is that magnesium-diboride-based material may be able to carry more current than the copper oxide superconductors. Furthermore, magnesium diboride may not need to be cooled with liquid helium as conventional superconductors are, but rather by electrical refrigeration (Dagani, 2001).

The world's fine chemicals industry displayed its wares and expertise in Milan, Italy, for the Conference on Pharmaceutical Ingredients. Companies introduced new intermediates in their catalogs and unveiled new technologies for producing chemicals to special order. Digital Specialty Chemicals, Dublin, NH, offered oxazaphospholidines that were made by reaction of phenylphophine-borane with either ephedrine or pseudoephedrine, which are opposites and thus may induce opposite configurations in products (Stinson, 2000).

A senior scientist at Haldor Topsoe Research Laboratories, Lyngby, Denmark, prepared a barium-promoted boron nitride catalyst to synthesize ammonia. The catalyst was prepared from boron nitride crystals and aqueous solutions of ruthenium nitroso nitrate and barium hydroxide (Chemical & Engineering News, 2001).

Boriding, the diffusion of boron into the surface of metals, increases the wear and corrosion resistance of the metals. Boron is an element of relatively small atomic radius, which allows it to diffuse into a variety of metals, such as ferrous metals, metal-bonded carbides, and nickel alloys. Boron reacts with ferrous alloys to form Fe_2B with Knoop hardness in the range of 1,500 to 1,700. The significant increase in case hardness results in substantial reduction of wear and galling (Cataldo and others, 2000).

Laser surface engineering (LSE) is a surface modification process in which a high power laser beam melts a ceramic powder precursor along with a thin layer of substrate to produce a laser melt zone. LSE of titanium diboride coating is a two stage process. In stage 1, a precursor layer of titanium diboride in a water-based organic solvent is deposited on an AISI 1010 steel substrate. In stage 2, an industrial grade laser melts a thin layer of the steel substrate. The titanium diboride powder becomes embedded in the molten steel creating a composite coating. The most significant properties of the coating are its corrosion resistance, modulus of elasticity, hardness, oxidation resistance, smoothness, strong interface, and wear resistance (Agarwal and Dahotre, 2000).

Room-temperature ionic liquids, formerly called molten salts, typically consisting of nitrogen-containing organic cations and inorganic anions are potential "green" [enviromentally friendly] designer solvents because they have no detectable vapor pressure and can make synthetic processes more efficient, resulting in a lower usage of raw materials. The organic cations are mated with inorganic anions, such as boron tetrafluoride. Ionic liquids are inherently ionically conductive, can mitigate self-discharge, and are virtually nonvolatile, nonflammable, and less toxic than conventional electrolytes. The electrochemical potential is usually much greater than for aqueous electrolytes. There is substantial interest in using ionic liquids as battery electrolytes. Researchers at the U.S. Air Force Academy are studying a dual intercalating molten electrolyte (DIME) battery. Research has shown that boron tetrafluoride works in the DIME battery (Freemantle, 2000).

Outlook

The demand for boron in the United States is expected to remain strong. New applications in gypsum board and strong demand in the glass industry are expected to increase consumption. Boron compounds and chemicals can reduce energy use in the creation process of many products. This may become an important sector if energy costs continue to rise. Although South America has large reserves of boron minerals, location, infrastructure, and processing problems have delayed significant production. The world production amounts for Turkey in table 7 do not accurately reflect production because some ore that was once exported is now being consumed as boron products for sale to Asia and Europe. World demand is expected to grow, primarily in the glass industry.

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References Cited

Advanced Material & Processes, 2000, Materials business—Advanced Ceramics Corp.: Advanced Materials & Processes, v. 157, no. 6, June, p. 21.

Agarwal, Arvinda, and Dahotre, N.B., 2000, Laser surface engineering of titanium diboride coatings: Advanced Materials & Processes, v. 57, no. 4, April, p. 43-45.

Akin, Y., Hancer, M., Celik, M.S., and Miller, J.D. 2000, Interaction of a mine with borate species in boron flotation pulps: Society for Mining, Metallurgy, and Exploration Annual Meeting, Salt Lake City, UT, February 28-March 1, 2000, Reprint 00-38, 6 p.

Baele, S., 2000, Boron: Mining Engineering, v. 52, no. 6, June, p. 29-30.

Bhatia, Tarun, 2001, Borates to the rescue: Borax Pioneer, no. 20, p. 4-5.

Borax Pioneer, 2000a, Smart suds: Borax Pioneer, no. 18, p. 10-11.

———2000b, Steel yourselves: Borax Pioneer, no. 18, p. 19.

Carr, Malcolm, 2000, Borates—Refining the art of continuous strand glassfiber: Glass, v. 77, no. 10, p. 331.

Cataldo, John, Galligani, Frank, and Harraden, Dave, 2000, Boride surface treatments: Advanced Materials & Processes, v. 157, no. 4, April, p. 35-38.

Chemical & Engineering News, 2000a, DOE, utility cut deal on radioactive waste: Chemical and Engineering News, v. 78, no. 31, July 31, p. 27.

———2000b, Science/technology concentrates—Carborane superacid protonates buckyball: Chemical & Engineering News, v. 78, no. 28, July 10, p. 46.

———2000c, Science/technology concentrates—"Merry-go-round" alkylation mechanism: Chemical & Engineering News, v. 78, no. 44, October 30, p. 33.

———2000d, Science/technology concentrates—New anion family is weakly coordinating: Chemical & Engineering News, v. 78, no. 41, October 9, p. 47.

———2000e, Science/technology concentrates—Polymer backbones built one atom at a time: Chemical & Engineering News, v. 78, no. 47, November 27, p. 21.

———2001, Science & technology concentrates—Boron nitride boosts catalyst activity: Chemical & Engineering News, v. 79, no. 18, April 30, p. 33.

Chemical Market Reporter, 2000, Albemarle supplies zinc borate: Chemical Market Reporter, v. 257, no. 19, p. 3.

———2001, Borax names distributor: Chemical Market Reporter, v. 258, no. 2, p. 29.

Cook, Simon, 2000, Virtually vitreous: Borax Pioneer, no. 18, p. 12.

Craig, Rochelle, 2000, California boron mine institutes "safety management audit training (SMAT)": North America Quarry News, v. 2, no. 5, May, p. 3.

Dagani, Ron, 2001, News of the week—Science—Superconductor stuns physicists: Chemical & Engineering News, v. 79, no. 10, March 5, p. 13.

Edbrooke, P.A., 2000, Borates—Sustainable development in the new millennium: Industrial Minerals, no. 393, June, p. 71-75.

Freemantle, Michael, 2000, Eyes on ionic liquids: Chemical & Engineering News, v. 78, no. 20, May 15, p. 37-50.

Garrett, Rodney, 2000, Rio Tinto Borax quick off the mark: Mining Magazine, v. 183, no. 4, October, p. 18-25.

Hunold, Klaus, 2000, Resistant refractories: Ceramic Industry, v. 150, no. 2, February, p. 34-42.

Industrial Minerals, 2000, Borax & Albemarle flame retardants j-v: Industrial Minerals, no. 389, February, p. 14.

———2001, Borax in confidentiality breach court case: Industrial Minerals, no. 404, May, p. 17-18.

Lloyd, Jeff, 2000, Borates—The best of biostat: Borax Pioneer, no. 19, p. 8.

Mining Engineering, 2000a, Nevada State engineer sued over Yucca Mountain water permits: Mining Engineering, v. 52, no. 5, May, p. 21.

———2000b, New technology allows reprocessing of borate reserves: Mining Engineering, v. 52, no. 11, November, p. 14.

O'Driscoll, Mike, 2001, Borates—The turk of the town: Industrial Minerals, no. 402, March, p. 30-45.

Rio Tinto, 2000, Rio Tinto 2000 annual report and financial statements: London, Rio Tinto plc, 140 p.

Rouhi, A.M., 2000, Biomaterial body shop: Chemical & Engineering News, v. 78, no. 26, June 26, p. 34.

Stinson, S.C., 2000, Fine chemicals fair: Chemical & Engineering News, v. 78, no. 49, December 4, p. 35-44.

Terry, D.L., and Kirby, B.J., 2001, Commercial fertilizers 2000: Association of American Plant Food Control Officials and The Fertilizer Institute, 38 p.

Tullo, A.H., 2001a, A fuel cell in every car: Chemical & Engineering News, v. 79, no. 10, March 6, p. 22.

———2001b, DuPont opens up boron business: Chemical & Engineering News, v. 79, no. 16, April 16, p. 19.

Washington Times, 2000, Tortoise vs. tank: Washington Times, September 10, p. C-1, C-8.

Zurer, Pamela, 2000, General ketone synthesis safe for base-sensitive groups: Chemical & Engineering News, v. 78, no. 48, November 27, p. 26.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Boron. Ch. in Mineral Commodity Summaries, annual.

Evaporites and Brines. Ch. in United States Mineral Resources, U.S. Geological Survey Professional Paper 820, 1973.

TABLE 1
SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Sold or used by producers:					
Quantity:					
Gross weight 2/	1,150	1,190	1,170	1,220	1,070
Boron oxide (B_2O_3) content	581	604	587	618	546
Value	$519,000	$580,000	$486,000	$630,000	$557,000
Exports: 3/					
Boric acid: 4/					
Quantity	42	92	106	107	119
Value	$35,300	$60,500	$54,600	$56,700	$64,400
Sodium borates:					
Quantity	381	473	453	370	413
Value	$133,000	$169,000	$146,000	$180,000	$136,000
Imports for consumption:					
Borax:					
Quantity	11 5/	54 5/	14 3/	8 3/	1 3/
Value	$3,470	$17,000	$5,160	$2,840	$716
Boric acid:					
Quantity	25 5/	26 5/	23 3/	30 3/	39 3/
Value	$10,800 e/	$11,800 e/	$12,500	$14,000	$17,500

See footnotes at end of table.

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TABLE 1--Continued
SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States--Continued:					
Imports for consumption--Continued:					
Colemanite:					
Quantity	44 5/	44 5/	47 5/	42 5/	26 5/
Value	$13,000 e/	$13,000 e/	$13,900	$13,100	$7,410
Ulexite:					
Quantity	136 5/	157 5/	170 5/	178 5/	127 5/
Value	$27,200	$31,400	$34,000	$35,700	$31,800
Consumption, boron oxide (B_2O_3) content	367	403	NA	416	360
World production	4,330	4,570	4,660 r/	4,380 r/	4,220 e/

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to no more than three significant digits.
2/ Minerals and compounds sold or used by producers, including actual mine production, and marketable products.
3/ Source: U.S. Census Bureau.
4/ Includes orthoboric and anhydrous boric acid. Harmonized Tariff Schedule (HTS) codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.
5/ Source: Journal of Commerce Port Import Export Reporting Service.

TABLE 2
BORON MINERALS OF COMMERCIAL IMPORTANCE 1/

Mineral	Chemical composition	Boron oxide (B_2O_3) weight percent
Boracite (stassfurite)	$Mg_6B_{14}O_{26}C_{12}$	62.2
Colemanite	$Ca_2B_6O_{11}•5H_2O$	50.8
Datolite	$CaBSiO_4•OH$	24.9
Hydroboracite	$CaMgB_6O_{11}•6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7•4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19}•7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9•5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2•2OH$	41.4
Tincal (natural borax)	$Na_2B_4O_7•10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7•5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9•8H_2O$	43.0

1/ Parentheses include common names.

TABLE 3
U.S. CONSUMPTION OF BORON MINERALS AND COMPOUNDS, BY END USE 1/ 2/

(Metric tons of boron oxide content)

End use	2000
Agriculture	13,900
Borosilicate glasses	24,400
Enamels, frits, glazes	13,800
Fire retardants:	
Cellulosic insulation	10,900
Other	1,980
Insulation-grade glass fibers	170,000
Metallurgy	488
Miscellaneous uses	5,430
Nuclear applications	454
Soaps and detergents	23,600
Sold to distributors, end use unknown	30,900
Textile-grade glass fibers	64,500
Total	360,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes imports of borax, boric acid, colemanite, and ulexite.

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TABLE 4
YEAREND 1999 PRICES FOR BORON MINERALS AND COMPOUNDS PER METRIC TON 1/

Product	Price, December 31, 1999 (rounded dollars)	Price, December 31, 2000 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carload, works 2/	637	637
Borax, technical, anhydrous, 99%, bags, carload, works 2/	846	846
Borax, technical, granular, decahydrate, 99%, bags, carload, works 2/	378	378
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works 2/	374	374
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works 2/	426	426
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works 2/	376	376
Boric acid, technical, granular, 99.9%, bags, carload, works 2/	834	834
Boric acid, technical, granular, 99.9%, bulk, carload, works 2/	788	788
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound-bags, carlots	1,972	1,996
Colemanite, Turkish, 42% B_2O_3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC 3/	290	270-290
Ulexite, Chilien, 38% B_2O_3, ground to a minus 6-mesh, f.o.b railcars, Norfolk, VA e/	200	200

e/ Estimated.

1/ U.S. free on board (f.o.b.) plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

2/ Chemical Marketing Reporter, v. 259, no. 1, January 2001, p. 18.

3/ Industrial Minerals, no. 399, December 2000, p. 70.

TABLE 5
U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY 1/

	1999			2000		
	Boric acid 2/		Sodium	Boric acid 2/		Sodium
Country	Quantity (metric tons)	Value (thousands)	borates 3/ (metric tons)	Quantity (metric tons)	Value (thousands)	borates 3/ (metric tons)
Australia	3,550	$1,700	7,010	2,290	$1,090	5,600
Belgium	--	--	8	--	--	(4/)
Brazil	3,540	1,470	1,210	5,140	1,930	1,070
Canada	4,610	3,040	42,900	4,410	2,930	42,100
Colombia	143	140	2,140	195	184	2,940
France	--	--	(4/)	--	--	1
Germany	360	216	15	1,020	731	3
Hong Kong	209	$117	378	121	$66	181
India	258	109	2,860	19	13	337
Indonesia	1,990	1,320	11,300	577	315	5,190
Israel	19	16	(4/)	5	4	(4/)
Japan	11,900	10,100	23,300	15,600	11,800	26,400
Korea, Republic of	11,600	7,240	14,900	9,810	5,740	17,900
Malaysia	1,350	899	7,690	2,210	1,290	7,730
Mexico	3,580	2,290	20,400	3,670	2,300	28,000
Netherlands	34,100	13,200	149,000	36,800	19,100	194,000
New Zealand	376	191	2,200	342	151	2,300
Philippines	151	93	1,800	19	15	2,010
Singapore	165	114	732	506	289	559
South Africa	--	--	82	--	--	39
Spain	8,790	3,050	49,000	11,700	3,790	43,400
Taiwan	8,730	4,990	10,400	11,700	6,150	8,880
Thailand	1,730	1,110	6,800	1,840	1,010	6,010
United Kingdom	84	98	96	188	162	109
Venezuela	222	253	640	213	205	362
Other	9,540	4,990	15,000	11,100	5,180	18,300
Total	107,000	56,700	370,000	119,000	64,400	413,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Harmonized Tariff Schedule (HTS) code 2810.00.0000.

3/ HTS codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.

4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Argentina	112	$46	59	$40
Belgium	2	6	2	5
Bolivia	5,750	2,340	2,530	982
Canada	23 r/	16 r/	--	--
Chile	12,400	5,330	14,900	6,140
France	2	6	20	63
Georgia	53	35	--	--
Germany	123	103	21	37
Italy	1,770	1,680	5,010	3,210
Japan	26	50	8	14
Peru	1,680	771	1,500	618
Russia	380 r/	222 r/	839	368
Turkey	7,870	3,410	14,300	6,000
United Kingdom	3	12	--	--
Total	30,200	14,000	39,200	17,500

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ U.S. Customs declared values.

Source: U.S. Census Bureau.

TABLE 7
BORON MINERALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Argentina	342	423	350	360 r/ e/	360
Bolivia (ulexite)	9	12	7 r/	7 r/	7
Chile (ulexite)	149	171	280	200	200
China e/ 3/	157	136 4/	137 4/	110	105
Germany (borax) e/	2	1	1	1	1
Iran (borax) e/ 5/	1	(6/) r/	2 r/ 4/	4 r/ 4/	4
Kazakhstan e/	30	30	30	30	30
Peru e/	39 4/	40	40	40	40
Russia e/ 7/	1,000	1,000	1,000	1,000	1,000
Turkey 8/	1,447	1,569	1,650 e/	1,410 e/	1,400
United States 9/	1,150	1,190	1,170	1,220	1,070 4/
Total	4,330	4,570	4,660 r/	4,380 r/	4,220

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through May 18, 2001.
3/ Boron oxide (B_2O_3) equivalent.
4/ Reported figure.
5/ Data are for years beginning March 21 of that stated.
6/ Less than 1/2 unit.
7/ Russian borate ore reportedly grades 8.6% B_2O_3.
8/ Concentrates from ore.
9/ Minerals and compounds sold or used by producers, including actual mine production and marketable products.

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BROMINE

By Phyllis A. Lyday

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Bromine is a natural element widely found in nature, principally in seawater, salt lakes, and underground brines associated with oil. The quantity of bromine sold or used in the United States was 228 million kilograms (Mkg) valued at $206 million (table 1). The value of bromine sold or used was $0.90 per kilogram (table 3). Primary uses of bromine compounds were in flame retardants (40%), drilling fluids (24%), brominated pesticides (mostly methyl bromide) (12%), water-treatment chemicals (7%), and others, including photographic chemicals and rubber additives (17%) (Chemical Market Reporter, 1999a). International distribution of bromine production for 2000 was estimated to be as follows: the United States, 45%; Israel, 35%; China, 9%; the United Kingdom, 5%; and other countries, 6% (table 6). Because of depleting reserves, distribution and economics, environmental constraints, and the emergence of Israel as the world's second largest producer with 36% of the world market, the U.S. portion of world production decreased steadily since 1973, when the United States produced 71% of the world supply, to 42% in 2000.

Legislation and Government Programs

Methyl bromide was listed as a class I ozone-depleting substance in the 1990 Clean Air Act (CAA) and was scheduled to be phased out in the United States by January 1, 2001. The U.S. Congress extended the phase out of methyl bromide until January 1, 2005, to coincide with the deadline for developed countries under the Montreal Protocol on Substances that Deplete the Ozone Layer. Under the Clean Air Act Amendments of 1990 (Public Law 101-549), U.S. production and imports of bromine must be reduced from 1991 levels as follows: 25% by 1999; 50% by 2001; 70% by 2003; and a full ban by 2005. Domestically, methyl bromide had proven to be a difficult pesticide to replace because of its low cost and usefulness against a large variety of agricultural pests. The amendment allowed for the exemption of critical uses of methyl bromide that have not been yet defined. The dominant use was for preplanting soil treatments. It also was used for structural applications, such as termite treatments. The United States consumed methyl bromide as a preplant fumigant for tomatoes (30%), strawberries (19%), and peppers, (14%). About 50% was consumed in California and 30% in Florida. (Hess, 2000). Three producers, Albemarle Corp., Great Lakes Chemical Corp., and Israel's Dead Sea Bromine Co. Ltd. (DSB), were the major manufacturers. Under the Montreal Protocol, developing countries had until 2015 to phase out methyl bromide production.

A report by environmental groups that predicted a national assessment of how global warming might affect the U.S. climate over the next 100 years was criticized by the Competitive Enterprise Institute as "a scientifically dishonest, alarmist document based on junk science." Critics stated the report sought to advance "a political agenda rather than look at the state of the science and its uncertainties involving the theory of climate change." Other deficiencies were predictions about future weather conditions that were "simply not scientifically possible with current technology" (Chemical

Bromine in the 20th Century

In 1901, production of bromine from brines associated with salt production was reported by the U.S. Geological Survey from Michigan, Ohio, Pennsylvania, and West Virginia to be 245,867 kilograms (542,043 pounds) valued at $154,472. The consumption was primarily for use in medicine, photography, and analytical and experimental chemistry. As bromine became more readily available, uses increased and included dissolving gold and separating it from platinum and silver, acting as an oxidizer, and uses in disinfectants, salts, and aniline dyes. During World War I, bromine was used extensively in asphyxiating gases in Europe. By 1918, bromine production had increased in quantity to 783,426 kilograms (1,727,156 pounds) valued at $970,099. In 1921, tetraethyl lead was used to reduce knock or pinging in internal-combustion engines. Bromine sold by producers in 1924 increased to 922,519 kilograms (2,033,804 pounds) valued at $594,685 as a result of use in the manufacture of ethylene dibromide used as a scavenger for tetraethyl lead. In 1924, E.I. du Pont de Nemours & Co. Inc. conducted successful experiments to produce bromides from seawater on a specially equipped ship named U.S. *Ethyl*. Dow Chemical Co. found bromine-rich brines in Midland, MI, and began production in 1925. By 1930, over 1,350 metric tons (3 million pounds) of bromine was produced. Bromine production began in Arkansas in 1965, and Arkansas quickly became the world's leading bromine producer. Ethylene dibromide continued to be the major use for bromine until lead was banned in gasoline in 1976 and was phased out by 1978.

In 2000, U.S. production of 228 tons valued at $206 million came from brines in Arkansas and Michigan. Bromine markets included the oil- and gas-well drilling industry, automobile tires, soil and grain fumigation, photographic papers and chemicals, gold ore processing chemicals, fire retardants for plastics, and biocides in indoor hot tubs, swimming pools, and recirculatory cooling systems.

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Market Reporter, 2000e).

The U.S. Environmental Protection Agency (EPA) announced a new office for information management, information policy, and technology stewardship that would be headed by a national program manager. The new office included the highly visible Toxics Release Program, which had been run in the past in the Office of Pollution Prevention and Toxics. The data collection and analysis functions that had been scattered throughout the agency would be consolidated to include environmental statistics, one-stop reporting, single-facility identification, and watershed information (U.S. Environmental Protection Agency, [undated], Pesticides, toxics and chemical projects and programs, accessed April 25, 2000, at URL http://www.epa.gov/epahome/pestoxpgram.htm).

Bromine was taxed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) (Public Law 96-510) that had gone through two reauthorizations since its enactment in 1980. The 1986 Superfund Amendments and Reauthorization Act (Public Law 99-499) made considerable changes to the remedy selection component of the law. A second reauthorization in 1990 extended only the program and its taxing authority. Superfund taxes on industry, which generated $1.6 billion per year, had not been collected since December 1995. The Superfund Trust Fund was projected to run out of money in 2000. By yearend, the Superfund had not been amended.

The EPA, the Environmental Defense Fund, and the American Chemistry Council announced that 192 of the Nation's largest chemical and oil companies, including 2 that produce bromine, had volunteered to ensure that approximately 1,100 commonly used chemicals were screened for basic toxicity; the companies were Chemical Manufactures Association (CMA) members (Johnson, 1999). The agreement was a significant step toward gathering complete screening data for 2,800 high production volume chemicals that were used or imported in quantities exceeding 454 metric tons per year (t/yr) (1 million pounds per year). CMA's Internet tracking publicly displayed the chemicals and timetables set for the companies (Chemical Manufacturers Association, [undated], HPV challenge website, accessed April 25, 2000, at URL http://www.cmahq.com). The Council of Chemical Associations, an international industry trade association, set a goal of testing 1,000 chemicals by 2004. The toxicity testing would be carried out under a cost-sharing program operated by the Organization of Economic Cooperation and Development, which comprised 29 countries, including the United States. The Synthetic Organic Chemical Manufacturers Association announced its support of the program as a result of commitments made by the EPA.

The EPA published in the Federal Register of December 7, 1999, its final rule for the revisions to the underground injection control regulations for class V injection wells. A study was conducted to develop background information used to evaluate the risk of these wells to underground sources of drinking water and to determine whether additional Federal regulation was warranted. Bromine was included in volume 9, "Spent Brine Return Flow Wells." In Arkansas, all 74 of the class V spent brine return wells were associated with facilities that produced bromide compounds from brine extracted from the Smackover Formation 6,000 feet below the lowermost underground source of drinking water (USDW). The chemical characteristics of the injected spent brine were determined primarily by the characteristics of the brine that was withdrawn for processing. In Arkansas, available data indicated that concentrations of barium and boron in spent brine routinely exceed primary maximum contaminant levels or health advisory levels. Arkansas was an underground injection code (UIC) primacy state for class V wells, so the Arkansas Oil and Gas Commission had jurisdiction over permitting, construction, and operation requirements. In Michigan, 24 spent brine wells were associated with production of magnesium, bromide, and calcium compounds from the Filer Sandstone Formation 2,000 feet beneath the lowermost USDW. In Michigan, EPA region 5 implemented the UIC class V program. In addition, the Geological Survey Division of the Michigan Department of Environmental Quality had authority to establish standards for construction, testing, operations, and plugging and abandonment of mineral wells and to permit such wells (U.S. Environmental Protection Agency, September 30, 1999, The class V underground injection control study—Volume 9—Spent brine return flow wells, accessed April 18, 2001, at URL http://www.epa.gov/safewater/uic/classv/volume9.pdf).

The U.S. Department of Transportation published a notice of final rulemaking for the Research and Special Programs Administration amending certain requirements in the hazardous materials regulations to enhance safety and to align with international standards. Changes to the hazardous materials table included removing 1-chloro-3-bromopropane and adding 1-bromo-3-chloropropane (U.S. Department of Transportation, 2000).

The Consumer Product Safety Commission held public hearings in 1998 to receive scientific and technical information relating to the toxicity, exposure, bioavailability, and environmental effects of flame retardant chemicals, including bromine compounds, that may be suitable for use in residential upholstered furniture. The Commission would evaluate the information obtained from the hearings as part of its deliberations on whether to propose a standard to address the hazard associated with small open-flame ignitions of upholstered furniture. At yearend 1999, the study was still in the information-gathering stage. In 2000, the study was in the draft stage.

The U.S. Department of Justice (DOJ) and the European Commission had been investigating the bromine industry for possible violations of antitrust laws. DSB pleaded guilty and paid a $7 million criminal fine for participating in a price-fixing conspiracy to eliminate competition in connection with the sale of certain flame-retardant products [tetrabromobisphenol-A (TBBA) and decabromodiphenyloxide] and the fumigant methyl bromide in the United States. Great Lakes had been granted U.S. amnesty from criminal prosecution in the investigation. DSB was charged with fixing prices in the United States between July 1995 and April 1998. The continuing investigation was being conducted in the DOJ Antitrust Division's field office in Dallas and the Federal Bureau of Investigation (Chemical Market Reporter, 2000g; Industrial Minerals, 2000e).

The EPA asked the chemical manufacturers to voluntarily test 23 substances, including ethylene dibromide, to which children were exposed in everyday life. The EPA would use data generated in the first round of its Voluntary Children's Chemical Evaluation Program to examine the risk from chemicals found in the human body that come from food,

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water, or air. The agency planned to evaluate and revise the program after the first tests and to expand it to include more chemicals (Hogue, 2001).

Production

Domestic production data for bromine were developed by the U.S. Geological Survey from a voluntary survey of U.S. operations. Of the operations to which a survey request was sent, six responded, representing 100% of total elemental bromine produced (table 1).

Albemarle's bromine production included three plant sites in south Arkansas with the addition of their new satellite facility in Union County, which was started up in July 2000. Albemarle had 31 bromine production wells, 6 of which also produced oil. Brine wells were twice as wide and twice as deep as typical Arkansas oil wells, and the brine that was produced exceeded 110° C (230° F). Albemarle owned 17.4% of the production from the west unit operated by Great Lakes in Union County and, as a result, produced bromine at their satellite plant from five additional wells in the unit.

Albemarle reported that the 50,000-t/yr TBBA plant was operational in Magnolia, AR. An improved TBBA, marketed under the trade name SAYTEX CP-2000, was widely used in many plastics systems. CP-2000 was used in reactive monomer in polycarbonates and epoxy polymers and was a major reactive component in epoxy oligomers used as an additive (nonreacting) flame retardant in acrylonitrile-butadiene-styrene systems. Albemarle began producing CP-2000 in late 1999 by use of a patented continuous reacting process. This distinguished CP-2000 from all other competitive offerings of TBBA that were produced by a batch reaction process.

Bromine flame retardants were used in electronic equipment to increase the fire resistance of the plastic housings and the computer printed circuit boards. TBBA also was used in carpets, computer housings and electrical connectors, and office furniture (Warren, 2000). These applications included communications, construction, electronics, textiles application, and transportation (42%). According to Albemarle, other bromine derivatives end uses were: pharmaceuticals, photography, rubber, and water treatment (30%); gasoline additives and oilfield completion fluids (20%); and agricultural chemicals and fumigants (15%) (Chemical Market Reporter, 1999b). Albemarle received EPA approval for Stabrom™ 909 biocide (Chemical Market Reporter, 2000a). Albemarle expanded sales of brominated biocides to the 50 States and Europe. Albemarle also operated two bromine derivatives plants in France.

Albemarle and Borax Polymer Additives Group signed an agreement that allowed Albemarle to offer zinc borate flame- and smoke-suppressing products in Asia. Zinc borate can replace antimony oxide as a synergist and can be combined with other mineral-based additives to be used as a synergist with SAYTEX flame retardants (Chemical Market Reporter, 2000a).

Albemarle purchased Ferro Corp.'s Pyro-Chek® flame-retardants business along with a plant at Port-de-Bouc, France. Ferro retained ownership of its Hammond, IN, facility, but stopped manufacturing brominated polystyrene flame retardants at that site (Chemical Market Reporter, 2000b).

Great Lakes Chemical continued production of bromine from brines at four plants in Arkansas. The company also owned Associated Octel Co. Ltd. of the United Kingdom. Great Lakes reached an agreement to acquire Aqua Clear Industries LLC. Aqua Clear's products and retail markets were complementary to those of the Great Lakes subsidiary Bio-Lab, Inc. (Chemical Market Reporter, 2000h). Bio-Lab received regulatory clearance from the U.S. Food and Drug Administration for the use of BromiCide® in the manufacture of food-contact paper and paperboard.

TETRA Technologies, Inc. was one of the largest users of brominated products in the world. Calcium, sodium, and zinc bromide, collectively referred to as clear brine fluids (CBFs), were used in oil and gas applications. CBFs have high specific gravities and were used in completion and workover activities to reduce the likelihood of damage to the well bore and productive pay zone. Calcium bromide and zinc bromide were purchased from two domestic and one foreign manufacturer, and TETRA recycled calcium and zinc bromide CBFs repurchased from its oil and gas customers. The West Memphis, AR, facility produced calcium bromide and zinc bromide using zinc-containing sludge from electroplating operations and low-cost hydrobromic acid. TETRA began operation of merchant bromine, calcium bromide, and sodium bromide plant at the Dow Chemical Co. Ludington, MI, facility in mid-1998 using purchased crude bromine from Dow's calcium-magnesium chemicals operation. The liquid sodium bromide was sold to the industrial water treatment markets. TETRA also owned a plant in Magnolia, AR, that was designed to produce calcium bromide but was not operational in 2000. Approximately 13,400 hectares (33,000 gross acres) of bromine containing brine reserves in the vicinity of the plant were under lease (TETRA Technologies, Inc., 2000).

Consumption

Global estimates of world market share of brominated flame retardants (BFR) listed Great Lakes Chemical with 31%; Albemarle with 23%; DSB with 22%; and others with 24%. The demand for BFR was expected to reach 680 Mkg (1.5 billion pounds) by 2003, according to Cleveland-based Freedonia Group. Merrill Lynch estimated sales from BFR to be $210 million for Albemarle. Salomon Smith Barney estimated that Great Lakes sales were $271.7 million (Lerner, 2000). It was estimated that the world market for flame retardants for plastics stood at approximately $2.2 billion and would grow at 5% to 6% per year through 2003 (Chemical Business Newsbase, 1999c).

There were many different flame retardants that included bromine, chlorine, phosphorus, nitrogen, and other elements. Flame retardants are chemicals that suppress the combustion process. They prevent the spread of fires or delay the time of flashover so that people have additional time to escape. It is estimated that BFRs accounted for 39% of the worldwide market in 1998. Consumption by final application was reported as follows: electronics and electrical, 56%; building and construction, 31%; textile, 7%; and transformers, 6%. The distribution of BFR use in electrical and electronic components use was reported as follows: household appliances, 59%; printed wiring boards, 30%; connectors and relays, 9%; and wire and cabling, 2%. In 1999, consumption by region was as follows: Asia, 56.2%; the Americas, 28.7%; and Europe 15.1% (Bromine Science and Environmental Forum, 2000, An

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introduction to brominated flame retardants, accessed April 15, 2000, at URL http://www.bsef.com).

Albemarle's fine chemicals division also included surface actives, bromine, and oilfield chemicals. The company had manufacturing units in Feluy, Belgium; Port-de-Bouc, Thann, France; and Teesport, United Kingdom. The Teesport facility functioned as a custom manufacturing and oilfield chemicals plant.

The EPA's methyl bromide phaseout program stated that those applications still using methyl bromide by 2005 would do so because they had no choice. Methyl bromide was still the common chemical used to limit the spread of damaging insect populations around the world. The U.S. Department of Agriculture recommended the use of methyl bromide to treat wood packaging materials from China because of the lack of good alternatives. A voracious, nonnative insect pest had been found in material at 26 scattered warehouse and residential sites in 14 States. China could end up having to use more than 12,500 metric tons (t) of methyl bromide to treat wood destined for the United States. This would represent a 75% increase in use in Asia compared with 1996 levels for all applications, including soil treatment. The EPA figures showed that only 4,070 t, or about 6% of all methyl bromide used globally, was used to fumigate timber worldwide in 1996 (Reisch, 1998).

Pesticides, such as bromine compounds, were used to protect food from pests, such as bacteria, insects, mold, rodents, and weeds. In 1996, Congress passed the Food Quality Protection Act (FQPA) to improve the safety of food and to protect the public from exposure to pesticides. With the passage of this act, the jurisdiction of food-contact antimicrobials shifted from the Food and Drug Administration to the EPA. The EPA asserted that conclusions concerning the dangers of pesticides in food were not credible and were unnecessarily alarmist (Chemical Market Reporter, 1999c). The EPA set standards on the amount of pesticides that may remain on food if pesticides were applied. The FQPA set a tougher standard for pesticide use on food. By 2006, the EPA was required to review all old pesticides safety standards to make sure that their use on food met the new safety standard. If a pesticide was authorized that did not meet the safety standard, then the EPA would work with grocery stores to inform consumers of such pesticides and foods that might contain them.

World Review

Publication of the International Organization for Standardization (ISO) 9000 standards was planned for November 2000. Bromine operations were part of the 200,000 ISO-9000-based quality-management systems being operated worldwide to ensure internal efficiency and customer specified requirements for the product (International Organization for Standardization, [undated], ISO revisions, accessed July 2, 1999, at URL http://www.bsi.org.uk/bsi/services/isorevs.htm; International Organization for Standardization, [undated], Welcome, accessed July 2, 1999, at URL http://www.iso.ch).

Azerbaijan.—The Neftchala iodine-bromine plant produced 4,000 t/yr of bromine from waters from oil wells in the Neftchla and Khillinsky oilfields, Prikurinsky Basin. The bromine reserves were estimated to be 100,000 t. To modernize and commission the plant, an investment of $1.4 million was required (Industrial Minerals, 2000c).

China.—Ocean Chemicals Group, Asia's largest elemental bromine producer, opened its first European sales agency in Old Glossop, United Kingdom. The agency planned to market bromine and bromine derivatives produced in China. The group produced 75,000 t/yr of bromine and bromine derivatives with sales estimated to be $1.2 billion per year (Chemical Business Newsbase, 1999b).

Construction began on the first phase of a bromide manufacturing joint venture in Weifang, Shandong Province. The venture was split between the Dead Sea Bromine Group and Haiha Group of Weifang. The new plant would produce a range of high-technology products of which the company planned to export 60% (Industrial Minerals, 2000b).

Denmark.—The Danish Environmental Protection Agency had drawn up a plan to progressively limit and stop the use of BFRs. A major part of BFR consumption was in imported goods, such as cars, computers, and television sets. The plan contained a large number of initiatives, such as build-up knowledge, information to consumers, international regulation and cooperation, national agreements, standardization, and subsidies for the development of alternatives to BFRs (Ministry of Environment and Energy, 2000, Danish Environmental & Energy Newsletter—Brominated flame retardants—Denmark is to limit the use of brominated fire retardants, accessed September 14, 2000, at URL http://www.mex.dk/uk/bromin.asp).

European Union.—The European Commission created three separate pieces of legislation out of the original draft directive on waste electrical and electronic equipment, which served to intensify the focus on BFRs. Under the draft, substitution of other flame retardants for polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDE) in electrical and electronic equipment was required to be completed by January 1, 2008. Restrictions on the BFRs would ban some of the most effective flame retardants available at a time in which politicians and firefighters were requesting increased levels of flame retardants for plastics in certain electrical and electronics applications. The ban on PBB would not affect the plastics market; PBDE, however, was still a widely used flame retardant in electrical plastics. The Commission was concerned about landfilling, incinerating, and recycling plastics containing BFRs because the end product could contain brominated dibenzofurans and brominated dibenzo-p-dioxins, which may be toxic. Separating out all plastics containing BFRs would present an additional cost to waste management because some of the plastics were fully recyclable and others, which contained brominated epoxy oligomer, had distinct advantages in terms of recyclability (Mapleston, 2000).

France.—Elf Atochem SA continued to switch from producing bromide derivatives to fine chemicals at its Port-de-Bouc plant in southeast France. The complex included a 12,000-t/yr bromine plant that supplied the downstream units. The company invested $12.8 million in the plant to produce alkyl bromides and dibromide, as well as ultrapure hydrobromic acid. Autofina completed a new 1,200-t/yr bromo-acids and bromo-esters plant. Albemarle operated a bromine derivatives facility at Thann and a flame retardants plant at Port-de-Bouc. Most of the production of brominated intermediates was sold to the pharmaceutical industry (Industrial Minerals, 2000d).

India.—Tamil Nadu Salt Corp. Ltd. planned a bromine plant

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at the Valinokkam complex. The bromine would be a byproduct of salt production (Businessline, 1999, India—Tamil Nadu Salt Corp. to expand Valinokkam plant, accessed April 28, 2000, at URL http://www.proquest.umi.com).

Israel.—The production of bromine and potash began in 1931 at Kalia. The soluble minerals existed mainly as bromine and chloride anions and magnesium, potassium, and sodium cations. Bromine had been produced as a byproduct from waste bitterns associated with potash production from the Dead Sea since 1957 by DSB. After potash was removed in solar ponds, the waste bitterns were processed with chlorine to recover bromine. The brine contained 14,000 parts per million of bromine. The bromine-free bitterns were then processed to recover magnesium (Chemical Business Newsbase, 1999a).

In 1985, the Israeli Government began efforts to sell a share of Israeli Chemical Co. Ltd. (ICL) to offset an investment program. ICL was a group of chemical and mineral industrial companies, with commercial and marketing services, research institutes, and technical facilities. Israel Corp. bought an additional 17% stake in March 1997, which brought its total share of ICL to 41.9%. In 1997, the Israeli Government announced its decision to sell off its 31.5% stake of ICL valued at $441 million; the sale required the approval of the finance committee of the Israeli Parliament. In 1999, Potash Corp. of Saskatchewan planned to purchase as much as 30% of ICL.

DSB was a major producer of bromine and bromine compounds. The company was 89% owned by ICL. DSB, in turn, owned a number of subsidiaries. ICL made an offer to purchase the remaining 11% of DSB for $60 million (Chemical Market Reporter, 2000f). DSB had bromine manufacturing facilities at the Sdom plant and organic and inorganic bromine compounds at Ramat Hovav, and Broomchemie BV operated its subsidiary in the Netherlands (Chemical Business Newsbase, 1999d).

Japan.—Tosoh Corp. was Japan's only producer of bromine and hydrobromic acid used in the manufacture of dyes, flame retardants, pharmaceuticals, and photosensitive materials (Tosoh Corp., [undated], Bromines & flame retardants, accessed January 7, 2000, at URL http://www.tosoh.com/EnglishHomePage/tcdiv/tcdinbro.htm).

Jordan.—Jordan Bromine Co. Ltd., a joint venture between Arab Potash Co. (APC), its subsidiary Jordan Dead Sea Industries Co. (JODICO), and Albemarle Holdings Co. Ltd. of the United States, was incorporated in Jordan on January 11, 1999. APC had since purchased JODICO's shares in the joint venture resulting in a 50-50 joint venture between APC and Albemarle Holdings. A $150 million bromine complex in Safi included a 50,000-t/yr bromine plant, a 40,000-t/yr calcium bromide plant, and a 12,500-t/yr initial capacity TBBPA plant expandable to 37,500-t/yr. The plant would produce bromine for the merchant market and derivatives facilities, including inorganic bromides for oilfield completion fluids and TBBPA as a flame retardant, primarily for marketing in Europe and Asia (Kendall, 2000). Agra Monenco Inc. of Canada was awarded a contract to perform engineering, procurement, and construction management (Industrial Minerals, 2000a). Jordan Bromine obtained a loan from the European Investment Bank for the project.

Ukraine.—JSC Brom of Krasnoperekopsk, located at the Sivash Gulf on the Sea of Azov in Crimea, was reported to have 52,000 t/yr of bromine capacity (Industrial Minerals, 1998).

United Kingdom.—Production of bromine increased during 1999. Albemarle UK Ltd., a subsidiary of Albemarle, announced the acquisition of the Teesport operation of Hodgson Specialty Chemical Division of BTP plc for approximately $14 million. The Teesport facility was completed in 1991 and served as a custom manufacturing and oilfield chemicals plant. The addition of products that Teesport produced would complement Albemarle's clear completion fluids, amines, and chemicals to the oilfield services industry.

After bidding against Rhodia affiliate International Speciality Phosphates Group (ISPG) for Albright & Wilson (A&W), a maker of nonhalogenated flame retardants, Albemarle U.K. Holdings Ltd. sold its remaining shares (11%) of A&W stock to ISPG, a wholly owned subsidiary of Donau Chemie AG (Chemical & Engineering News, 1999a).

Current Research and Technology

Albemarle continued to improve its vacuum bromine recovery process that initially started up in June 1984, with the installation of a second generation vacuum bromine tower at its Magnolia facility in September 1998 and with the addition of a new bromine production facility in Union County, AR, in July 2000. Albemarle had three facilities in south Arkansas utilizing this patented two-stage vacuum bromine recovery technology consisting of a vacuum streamingout tower and a secondary steam recovery flash chamber. This highly efficient continuous recovery process made Albemarle globally more competitive by reducing bromine production costs and increasing tower capacity from that of prior technology.

Many biologically active agents were derivatives of natural products. A research team specializing in organic synthesis devised a new way to create large combinatorial libraries of such compounds. The new technique, developed by K.C. Nicolaou and coworkers at the Scripps Research Institute and the University of California was unique. A prenylated phenol group was immobilized on a polystyrene-based selenyl bromide derivative resin. The resin would be available commercially from Aldrich Chemical Co., Inc., Milwaukee, WI (Borman, 2000).

A research team at the National Center for Scientific Research of the University of Paris-South and Agfa Gervaert Group in Mortsel, Belgium, used a silver bromide dopant to improve the performance of photosensitive silver halide emulsions used to make photographic films. During the conventional photographic process, photons falling on silver halide microcrystals cause the halide ions to generate pairs of electrons and positive holes. The silver ions capture the electrons and the resulting neutral silver atoms group into clusters of metallic silver that form the latent image. This image was then developed into a visible image. This theoretical limit is one silver atom per absorbed photon. With the new dopant, formate ions produce carbon dioxide radicals that transfer energy to silver cations. The overall process is known as photo-induced bielectronic transfer because two electrons are generated. The bielectronic nanosilver halide system leads to the highest light efficiencies ever measured. All the light energy is used to produce the latent image without fogging the film (Chemical & Engineering News, 2000).

Researchers at Eastman Kodak in Rochester, NY, and at Arizona State University developed a photosensitization

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process that could double the speed of photographic materials. In the Kodak process, an additional electron donor molecule reacts with the oxidized dye forming a radical cation. This cation undergoes irreversible fragmentation to produce a radical that donates a second electron to the silver halide. The increase in sensitivity of silver halide allows more freedom in designing photographic systems (Freemantle, 2000).

A team that included specialists in environmental sciences, metallurgical processing, mining, water treatment, and worker health studied extraction technologies at the McDonald gold project near Lincoln, MT. Bromine/sodium bromide was one of five alternative technologies studied to process the gold ore. Using the bromine/sodium bromide process required fewer daily truck shipments than the other four processes studied. The chemical conditions required for gold leaching by the bromide lixiviants are strongly acidic (De Voto and McNulty, 2000).

In quantum mechanics, particles are described by spread-out wave functions, seemingly existing in many places at once. A computer made of quantum particles has a built-in parallelism, because quantum calculations can be performed on the particles coexisting states simultaneously. Materials used in nuclear magnetic resonance quantum computers include 2,3-dibromothiophene. When nuclei with spin are placed in a magnetic field, they align themselves either parallel or antiparalled to the field, with a slight excess in the parallel orientation. A pulse of electromagnetic radiation of the right frequency and duration will flip a nucleus. A quantum bit, or qubit, can be set up to exist in the 0 and 1 states at the same time. The first quantum computer of Cory and colleagues of the Massachusetts Institute of Technology consisted of two hydrogen qubits in the molecule 2,3-dibromothiophene (Wilson, 2000).

Outlook

Petroleum.—Demand for bromine as a gasoline additive has declined each year since the EPA issued regulations in the 1970s to reduce and eliminate lead in automotive gasoline. In 1979, the amount of bromine sold for this application reached a peak of 225 Mkg. The rapid decline to 141 Mkg in 1986 was a direct result of the limits on lead in leaded automotive gasoline. The European Community continued discussions to reduce lead levels in gasoline. Bromine in petroleum additives was expected to continue to decline over the long term. Federal laws enacted to encourage alternative forms of power in automotive engines are likely to have a depressive effect on bromine demand. The CAA requires mobile sources, such as cars and trucks, to use the most effective technology possible to control emissions. Electric cars were on the market in California. Newer prototypes of the fuel cell that burns gasoline can double the mileage and thereby decrease emissions by using unleaded gasoline.

Sanitary Preparations.—Bromine was used in indoor swimming pools, hot tubs, and whirlpools. The sanitary preparation field is an area where bromine is safer than its substitutes, because bromine has a higher biocidal activity level for the same amount of product. Growth areas are in the pulp and paper industry, cooling towers, and Government-regulated food-washing applications. Albemarle reported double-digit sales growth of brominated biocides as it replaced chlorine and other products in a variety of applications (McCoy, 1998).

Fire Retardants.—Bromine is a reactive flame retardant in that it enters into chemical reactions with the components of the systems in which it is used. In addition, bromine acts as a synergist with many other fire-retardant materials and so increases the effectiveness of the fire retardant. A new nonbrominated material, a precursor to polybenzoxazole (PBO), which is a polyhydroxyamide that upon heating is converted to PBO, could limit flammability. This could have a major negative effect upon the use of BFRs, especially in airplanes, prisons, submarines, and ships (Chemical & Engineering News, 1999b).

Other Uses.—Use of calcium, sodium, and zinc bromides in well-completion fluids decreased during the 1980s as the domestic petroleum industry suffered a severe recession. In 1997, however, the oil-services sector posted another strong performance. About 95% of calcium bromide produced was used as an oil and gas completion fluid. Oilfield chemicals used in drilling, completion and workover, and production operations remained significantly more profitable internationally than in the United States. With the cutback of petroleum supplies internationally and the rising cost of energy for automobiles and heating, usage is expected to increase as new domestic wells are drilled and existing wells are serviced to become more productive.

References Cited

Borman, Stu, 2000, Science/technology—Naturally combinatorial: Chemical & Engineering News, v. 78, no. 44, October 30, p. 35-36.

Chemical & Engineering News, 1999a, Business concentrates—Business roundup: Chemical & Engineering News, v. 77, no. 23, June 6, p. 12.

———1999b, Letters—Fire-resistant polymers: Chemical & Engineering News, v. 77, no. 20, May 17, p. 6.

———2000, Dopant boosts AgBr emulsion photosensitivity: Chemical & Engineering News, v. 78, no. 1, January 3, p. 8.

Chemical Market Reporter, 1999a, Albemarle pushes ahead with multiple bromine projects: Chemical Market Reporter, v. 256, no. 6, August 9, p. 24.

———1999b, Chemical profile: Chemical Market Reporter, v. 256, no. 8, August 23, p. 37.

———1999c, Society of Toxicology denounces report on pesticide residues: Chemical Market Reporter, v. 255, no. 13, March 29, p. 20.

———2000a, Albemarle expands biocides: Chemical Market Reporter, v. 258, no. 17, October 23, p. 7.

———2000b, Albemarle inks Ferro buy: Chemical Market Reporter, v. 258, no. 1, July 3, p. 5.

———2000c, Asia brief—Albemarle Corp.: Chemical Market Reporter, v. 257, no. 20, May 15, p. 30.

———2000d, Climate changes from global warming outlined in report: Chemical Market Reporter, v. 258, no. 3, July 17, p. 17.

———2000e, Company news—ICL to buy rest of Dead Sea: Chemical Market Reporter, v. 258, no. 21, November 20, p. 3.

———2000f, Dead Sea Bromine pleads guilty: Chemical Market Reporter, v. 258, no. 6, August 7, p. 7.

———2000g, Great Lakes adds Aqua Clear: Chemical Market Reporter, v. 258, no. 1, July 3, p. 3.

Chemical Business Newsbase, 1999a, Asia Pacific Chemicals—Fanning the flame—Bromine and its derivatives: Chemical Business Newsbase, April 23, 1 p.

———1999b, Europa Chemie—China bromine booming in Europe: Chemical Business Newsbase, March 4, 1 p.

———1999c, European paint and resin news—Bromine compounds most widely used flame retardants for plastics: Chemical Business Newsbase, January 15, 1 p.

———1999d, Speciality chemicals—Dead Sea Bromine Group: Chemical Business Newsbase, March 4, 1 p.

De Voto, R.H., and McNulty, T.P., 2000, Banning cyanide use at McDonald—An attack on open-pit mining: Mining Engineering, v. 52, no. 12, December, p. 19-27.

Freemantle, Michael, 2000, News of the week—Doubling film speed, radically: Chemical & Engineering News, v. 78, no. 50, December 11, p. 9.

Digitized by Google

Hess, Glenn, 2000, Regulatory watch—Phase out of methyl bromide to impose significant costs on U.S. agriculture: Chemical Market Reporter, v. 257, no. 16, April 17, p. 27.
Hogue, Cheryl, 2001, Evaluating chemical risks facing children: Chemical & Engineering News, v. 79, no. 1, January 1, p. 8.
Industrial Minerals, 1998, Ukraine minerals: Industrial Minerals, no. 373, October, p. 41.
——— 2000a, Jordan—Agra wins JBC Safi Br contract: Industrial Minerals, no. 397, October, p. 16.
———2000b, Mineral notes—Weifang bromine underway: Industrial Minerals, no. 397, October, p. 105.
———2000c, News & Events—Iodine-bromine plant needs investor: Industrial Minerals, no. 399, December, p. 23.
———2000d, News in brief—Bromine—Atofina expands bromine in France: Industrial Minerals, no. 399, December, p. 31.
———2000e, World of minerals—Israel—DSBG pleads guilty to price fixing: Industrial Minerals, no. 396, September, p. 12.
Johnson, Jeff, 1999, News of the week—Industry to test 1,450-plus chemicals: Chemical and Engineering News, v. 77, no. 14, April 5, p. 8.
Kendall, Tom, 2000, Fertilizers bear fruit: Industrial Minerals, no. 398, November, p. 51.
Lerner, Ivan, 2000, Specialties newsfront—Flame retardant price increases show producer discipline: Chemical Market Reporter, v. 258, no. 10, September 4, p. 15.
Mapleston, Peter, 2000, Additives—EU legislation turns the heat on brominated flame retardants: Modern Plastics, v. 77, no. 9, September, p. 56.
McCoy, Michael, 1998, Biocides succeed despite regulations: Chemical & Engineering News, v. 76, no. 46, November 9, p. 21-39.
Reisch, Marc, 1998, Methyl bromide alternatives pose challenges to producers: Chemical & Engineering News, v. 76, no. 45, November 9, 46 p.
TETRA Technologies, Inc., 2000, Form 10-K FY2000: Securities and Exchange Commission, 80 p.
U.S. Department of Transportation, 2000, Research and special program administration: Federal Register, v. 65, no. 161, August 18, p. 50450-50463.
Warren, Susan, 2000, A new bromide-brine is much better than oil in Arkansas: Wall Street Journal, February 14, p. A1, A14.
Wilson, E.K., 2000, Quantum computer: Chemical & Engineering News, v. 78, no. 45, November 6, p. 35-39.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Bromine. Ch. in Mineral Commodity Summaries, annual.
Bromine. Ch. in Minerals Yearbook, annual.
Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Bromine. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675.

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TABLE 1
SALIENT BROMINE AND BROMINE COMPOUNDS STATISTICS 1/

(Thousand kilograms and thousand dollars)

	HTSUS 2/ number	1996	1997	1998	1999	2000
United States:						
Bromine sold or used: 3/						
Quantity		227,000	247,000	230,000	239,000	228,000
Value		$150,000	$111,000	$162,000	$201,000	$206,000
Exports: 4/ 5/						
Elemental bromine:	2801.30.2000					
Quantity		2,920	2,330	1,490	2,110	1,870
Value		$3,970	$3,590	$3,440	$2,430	$2,560
Bromine compounds: 6/	(7/)					
Gross weight		13,100	10,700	10,200	9,520	9,210
Contained bromine		11,100	9,050	8,550	8,020	7,740
Value		$22,100	$21,200	$18,000	$16,000	$26,200
Imports: 4/ 8/						
Elemental bromine:	2801.30.2000					
Quantity		415	1,650	1,200	1,970	5,470
Value		$305	$1,200	$1,060	$2,110	$3,730
Bromine compounds:						
Ammonium bromide:	2827.59.2500					
Gross weight		11,700 9/	33,000 9/	471 10/	1,510 10/	48,100
Contained bromine		9,370 9/	2,690 9/	384	1,240	3,930
Value		$9,580 9/	$22,000 9/	$1,280 e/	$1,940	$22,000
Calcium bromide:	2827.59.2500					
Gross weight 10/		--	803	350	--	7,860
Contained bromine		--	642	280	--	6,280
Value		--	$289	$213 e/	--	$4,780 e/
Potassium bromate:	2829.90.0500					
Gross weight		301 10/	378 10/	141	373	245
Contained bromine		144 10/	181	67	178	117
Value		$1,140 10/	$1,650 r/	$571	$1,470	$1,100
Potassium bromide:	2827.51.0000 11/					
Gross weight		733 10/	705 10/	910 10/	1,170	871 10/
Contained bromine		493	474	611	786	585
Value		$1,780	$1,710	$2,220 e/	$2,830 e/	$2,130
Sodium bromate:	2829.90.2500					
Gross weight		1,200	1,220	1,100	1,050	1,160
Contained bromine		634	646	584	554	615
Value		$3,030	$3,170	$2,900	$2,430 e/	$2,750
Sodium bromide:	2827.51.0000 11/					
Gross weight 10/		1,240	2,730	3,960	4,640	3,130
Contained bromine		965	2,120	3,070	3,600	2,430
Value		$1,910	$4,210	$6,090 e/	$5,540 e/	$4,820 e/
Other compounds:	2903.30.1550					
Gross weight		6,520	8,910	8,990	7,400	7,760
Contained bromine		5,090	6,900	6,770	785	582
Value		$14,900	$16,700	$18,900	$17,000	$15,500
World production e/		483,000	542,000	520,000 r/	550,000 r/	542,000

e/ Estimated. r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits.

2/ Harmonized Tariff Schedule of the United States.

3/ Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.

4/ U.S. Census Bureau.

5/ Export values are free alongside ship (f.a.s.).

6/ U.S. Census Bureau. Includes methyl bromine and ethylene dibromide.

7/ Data for these compounds are derived from HTSUS numbers 2903.30.0500, 2903.30.1500 (1996, 1997, 1998, and 1999), and 2903.30.1520 (2000) information.

8/ Import values are cost, insurance, and freight (c.i.f.).

9/ The respective data for "bromides/bromines and oxides" of ammonium, calcium, and zinc are combined and reported here; imports for 1996 included 568 thousand kilograms, and imports for 1997 included 83 thousand kilograms of zinc bromide.

10/ The Journal of Commerce Port Import/Export Reporting Service.

11/ Bromides of sodium or of potassium import data are usually reported by a mutual HTSUS number, 2827.51.0000.

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TABLE 2
ELEMENTAL BROMINE-PRODUCING PLANTS IN THE UNITED STATES, 2000

State and company	County	Plant	Production source	Capacity 1/ (million kilograms)
Arkansas:				
Albemarle Corp.	Columbia	Magnolia (a)	Well brines	
Do.	do.	Magnolia (b)	do.	140 2/
Do.	Union	Maryville	do.	12
Great Lakes Chemical Corp.	do.	Newell 3/	do.	25
Do.	do.	South	do.	
Do.	do.	El Dorado	do.	93 2/
Do.	do.	West	do.	59
Michigan, Dow Chemical Co.	Mason	Ludington 4/	do.	20
Total				349

1/ Actual production capacity is limited by brine availability.
2/ This represents the cumulative capacity of the two identified plant sites.
3/ Closed yearend 1999.
4/ Bromine produced at this plant is reprocessed in Arkansas.

TABLE 3
YEAREND 2000 PRICES FOR ELEMENTAL BROMINE AND SELECTED COMPOUNDS

Product	Value (cents) Per pound	Per kilogram
Bromine:		
Drums, truckloads, works 1/	123	271
Bulk, tank cars, works 1/	56-68	123-150
Bromochloromethane, drums, bulk, f.o.b. Magnolia, AR	127	280
Ethyl bromide, technical, 98%, drums, truckloads	127	280
Ethylene dibromide, drums, carloads	95	209
Hydrobromic acid, 48%, drums, carloads, truckloads, f.o.b.	56	123
Hydrogen bromide, anhydrous, cylinders, 2,500 pounds, truckloads	475	1,047
Methyl bromide, tank cars	77	170
Potassium bromate, granular, powdered, 200-pound drums, carloads, f.o.b. works	179	395
Potassium bromide, N.F., granular, drums, carloads, f.o.b. works	110-112	242-247
Sodium bromide, technical, truckloads	70	154

1/ Delivered prices for drums and bulk shipped west of the Rocky Mountains, 1 cent per pound higher. Bulk truck prices, 1 to 2 cents higher per pound for 30,000-pound minimum.

Source: Chemical Market Reporter. Current Prices of Chemicals and Related Materials, v. 258, no. 25, December 18, 2000, p. 23-28.

TABLE 4
U.S. IMPORTS OF OTHER BROMINE COMPOUNDS 1/ 2/

Compounds	HTSUS 3/ number	1999 Gross weight (kilograms)	1999 Value 4/ (thousands)	2000 Gross weight (kilograms)	2000 Value 4/ (thousands)	Principal sources, 2000
Hydrobromic acid	2811.19.3000	250	$285	370	$366	Israel, 89%; Germany, 10%; other, 1%.
Ethylene dibromide	2903.30.0500	506	553	2,000	2,020	United Kingdom, 98%; other, 2%.
Methyl bromide	2903.30.1520	2,300	5,000	671	1,690	Israel, 100%.
Dibromoneopentyl glycol	2905.50.3000	1,470	4,890	1,390	4,640	Do.
Tetrabromobisphenol A	2908.10.2500	752	1,380	700	1,030	Do.
Decabromodiphenyl oxide and octabromodiphenyl oxide	2909.30.0700	2,120	4,920	2,630	5,800	Do.
Total		7,400	17,000	7,760	15,500	

1/ These data detail the information included in table 1, imports of "Other bromine compounds."
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Harmonized Tariff Schedule of the United States.
4/ Declared cost, insurance, and freight valuation (c.i.f.).

Source: U.S. Census Bureau.

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TABLE 5
WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES, DECEMBER 31, 2000 1/

Country and company	Location	Capacity (thousand kilograms)	Source
Azerbaijan, Neftechala Bromine Plant	Baku	4,000	Underground brines.
China, Laizhou Bromine Works	Shandong	30,000	Do.
France:			
Atochem	Port-de-Bouc	12,000	Seawater.
Mines de Potasse d'Alsace S.A.	Mulhouse	2,300	Bitterns of mined potash.
India:			
Hindustan Salts Ltd.	Jaipur		Seawater bitterns from salt production.
Mettur Chemicals	Mettur Dam	1,500	
Tata Chemicals	Mithapur		
Israel, Dead Sea Bromine Co. Ltd.	Sdom	190,000	Bitterns of potash production from surface brines.
Italy, Societa Azionaria Industrial Bromo Italiana	Margherita di Savoia	900	Seawater bitterns from salt production.
Japan, Toyo Soda Manufacturing Co. Ltd.	Tokuyama	20,000	Seawater.
Spain, Derivados del Etilo S.A.	Villaricos	900	Do.
Turkmenistan:			
Nebitag Iodine Plant	Vyshka	3,200	Underground mines.
Cheicken Chemical Plant	Balkan	6,400	Do.
Ukraine, Perekopskry Bromine Plant	Krasnoperckopsk	3,000	Do.
United Kingdom, Associated Octel Co. Ltd.	Amlwch	30,000	Seawater.

1/ Excludes U.S. production capacity. See table 2.

TABLE 6
BROMINE: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country 3/	1996	1997	1998	1999	2000
Azerbaijan	2,000	2,000	2,000	2,000	2,000
China	41,400	50,100	40,000	42,000 r/	45,000
France	2,024 4/	1,974 4/	1,950 4/	2,000	2,000
India	1,500	1,500	1,500	1,500	1,500
Israel	160,000	180,000	185,000	185,000	185,000
Italy	300	300	300	300	300
Japan	15,000	20,000	20,000	20,000	20,000
Spain	100	100	100	100	100
Turkmenistan	102 4/	130 4/	150	150	150
Ukraine	3,000	3,000	3,000	3,000	3,000
United Kingdom	30,600 4/	35,600 4/	35,900 r/ 4/	55,000 r/ 4/	55,000
United States 5/	227,000 4/	247,000 4/	230,000 4/	239,000 4/	228,000 4/
Total	483,000	542,000	520,000 r/	550,000 r/	542,000

r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 17, 2001.

3/ In addition to the countries listed, several other nations produce bromine, but output data are not reported; available general information is inadequate to formulate reliable estimates of output levels.

4/ Reported figure.

5/ Sold or used by producers.

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CADMIUM

By Jozef Plachy

Domestic survey data and tables were prepared by Jason T. Collins, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2000, production of cadmium metal in the United States increased by nearly 60% compared with very low production in 1999; production of cadmium compounds, including cadmium sulfide, declined by more than 30% (tables 1, 2). Apparent consumption increased by nearly 9%, but, for the fifth consecutive year, exceeded production (tables 1, 3). The difference was made up by imports and sales from the National Defense Stockpile, operated by the Department of Defense. After years of consecutive decline, the price for cadmium metal registered a modest increase in 2000.

In the United States, two companies, one in Illinois and another in Tennessee, produced primary cadmium as a byproduct of the smelting and refining of zinc concentrates in 2000. A third company, in Pennsylvania, recovered cadmium from scrap, mainly from spent nickel-cadmium (Ni-Cd) batteries. In 2000, the value of cadmium produced was calculated to be about $670,000. Although definitive consumption data do not exist, the International Cadmium Association (ICdA) has made the following estimates of cadmium consumption for various end uses in 2000: batteries, 75%; pigments, 12%; coatings and plating, 8%; stabilizers for plastics and similar synthetic products, 4%; and nonferrous alloys and other uses, 1% (Hugh Morrow, President, International Cadmium Association, oral commun., 2001).

In 2000, as in most years, the United States was a net importer of cadmium metal. The major source of U.S. imports was Belgium, accounting for about 23% of all imports, followed by Mexico and Australia, with 20% and 18%, respectively (table 6). Cadmium compounds and pigments were subject to import duties, but unwrought and powdered metal, as well as waste and scrap, entered duty free in all but a few cases. Cadmium, in all forms, from North American Free Trade Association member nations (Canada and Mexico) entered the United States duty free. As in 1999, the United States was a net exporter of cadmium sulfide, most of which was exported to China (84%), followed by the Philippines (8%) and Hong Kong (5%) (table 5). Trade data for other cadmium compounds were not available.

Cadmium was refined in 28 countries in 2000 (table 7). The six largest producers, in decreasing order, were Japan, China, the United States, Belgium, Canada, and Mexico. These countries accounted for more than one-half of world production; the United States accounted for nearly 10%. Identified world cadmium resources at yearend 1999 were estimated by the U.S. Geological Survey (USGS) to be 6 million metric tons (Mt), a figure based on zinc resources typically containing about 0.3% cadmium. The world reserve base was estimated to be 1.2 Mt, and reserves were 600,000 metric tons (t).

Legislation and Government Programs

During the last decade, regulatory pressure to reduce or even eliminate the use of cadmium, a metal which is toxic in certain forms and concentrations, has gained momentum, mainly in the European Union (EU), and some other developed countries as well. In the United States, many Federal and State agencies regulate the cadmium content of air, water (including bottled water), pesticides, color and food additives, waste, etc. In 1999, the U.S. Environmental Protection Agency (EPA) created a draft list of persistent, bioaccumulative, and toxic (PBT) pollutants. Since its publication, the PBT list continues to be controversial not only in the cadmium industry but also in the base metal industry since all nonferrous metallic elements are inherently persistent but not necessary bioavailable.

Cadmium is 1 of 11 metals among 53 chemicals on the draft PBT list targeted by the EPA for a 50% reduction by 2005. The ICdA objected to the inclusion of any metal, particularly cadmium, on the PBT list. One of the reasons for its objection was that no distinction was made between various cadmium compounds and cadmium metal itself. According to ICdA, it is not possible to give a single rating for cadmium and all of its compounds because of their widely varying solubilities and bioavailabilities. Highly soluble and bioavailable cadmium chloride and cadmium ions, for example, will have a much

Cadmium in the 20th Century

Germany produced the first commercial cadmium metal at the end of 19th century and was the most important producer until the outbreak of World War I. Production in the United States began in 1907 when the Grasselli Chemical Co. of Cleveland, OH, recovered 6 metric tons of cadmium metal as byproduct of zinc smelting. As imports from Germany were curtailed during World War I, domestic production rapidly increased, and by 1917 the United States became the world's leading producer of cadmium. Increased production was spurred by the development of the cadmium electroplating process in 1919 to coat mainly iron and steel.

By the 1940s, electroplating represented about three-fourths of cadmium consumption. Production and consumption of cadmium in the United States peaked in 1969, at 5,700 tons and 6,800 tons, respectively. Since then, both production and consumption declined because of environmental concerns due to toxicity of certain forms of cadmium. During the second half of the 20th century, the primary use of cadmium was for plates in batteries. By 2000, about three-fourths of the cadmium consumption was for batteries and the remaining one-fourth is used for pigments, coatings and plating, and as stabilizers for plastics.

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different risk than cadmium metal, cadmium oxide, cadmium sulfide, and other insoluble compounds. Therefore, ICdA claims that the PBT rating for cadmium should recognize differences between the various forms of cadmium, their relative bioavailability, and thus their relative effects on human health and the environment. In addition, the draft PBT list failed to recognize that naturally occurring metallic elements are inherently persistent, but that such persistence results in less not more adverse environmental and human health effects. It is the bioavailable amounts of cadmium, according to ICdA, which are likely to lead to adverse health effects not the persistent amounts. During 2000, the opposition to the draft PBT list from various segments of industry, government, and academia continued to grow. Representatives of over 55 industry trade associations became signatories to a letter to EPA requesting a review of scientific documentation on which the list was based by its Science Advisory Board and seeking to defer inclusion of all metals in PBT programs until completion of that review. The trade associations assert that metals and inorganic metal compounds should be assessed under different criteria than synthetic organic chemicals for which the PBT methodology was first developed. The U.S. House of Representatives Committee on Science supported the industry by strongly encouraging EPA to review, as soon as possible, the scientific soundness of the methodology used in creating the PBT list (ILZRO Environmental Update, 2000b).

On another issue involving cadmium, the EPA decided to amend the existing Clean Water Act of 1995. The act requires the EPA to develop and, as warranted, revise water quality criteria so that its standards accurately reflect the latest scientific knowledge. The act also requires that water quality criteria be based solely on water data and scientific judgments; it does not consider economic impacts or the technological feasibility of meeting the criteria in ambient water. The latest revision involving cadmium was introduced on October 29, 1999, when EPA published the 2000 "Update of Ambient Water Quality Criteria for Cadmium" in the Federal Register. With this publication, the EPA made available to the public all references identified by a recent literature review and asked the public to submit any additional pertinent data or scientific views that would be useful in revising the aquatic life criteria for cadmium. The deadline for comments was October 17, 2000. After a careful review and incorporation of comments, an update of the Clean Water Act will be published in 2001 (U.S. Environmental Protection Agency, August 17, 2000, Notice of availability of draft aquatic life criteria document for cadmium, accessed November 25, 2000, at URL http://www.epa.gov/fedrgstr/EPA-WATER/2000/August/Day-17/w20972.htm). Most of the comments during the review period urged the EPA not to proceed with the cadmium update until the Biotic Ligand Model for cadmium was developed by the EPA which is considered a scientifically appropriate model to assess the toxicity of metals in aquatic environments. The model would integrate the physicochemical properties of the site-specific aquatic system, including pH, dissolved organic content, hardness, chloride content and alkalinity, with the biological component being protected. Consequently, the model would predict the bioavailability and toxicity of metals far more accurately than current methodologies. In many cases, this will result in more realistic criteria than those currently existing due to the incorporation of additional modifying factors (ILZRO Environmental Update, 2000d).

Because spent batteries are one of many sources of heavy metals emissions when incinerated or disposed of in landfills, certain European countries have adopted individual environmental standards on batteries containing cadmium, lead, and mercury. To avoid trade barriers created by disparities in such restrictions, the European Commission (EC) in 1991 unified these individual measures into Directive 91/157/EEC, which is binding for all EU member countries. The latest one, EU Directive 2000/60/EC on water, recommends phasing out the use of 32 chemicals over the next 20 years. The ban on Ni-Cd batteries is to start in 2008. If approved by the European Parliament, this directive will require all EU member countries to phase out the discharge of these hazardous chemicals into aquatic environments. Similar to the EPA, the Commission identified 11 of the chemicals for inclusion on a priority list of chemicals that they consider to be toxic, persistent, and liable to be bioaccumulate in the environment—the PBT list. Chemicals on this list, which includes cadmium, will be the first to be addressed by the Commission for possible phase out (ILZRO Environmental Update, 2001). In opposition to such a ban, the battery industry has proposed an EU-wide used battery collection scheme that would ensure recycling of at least 75% of Ni-Cd batteries possibly by 2004. ICdA argued that if the recycling goal is not achieved, cadmium could still be banned in time for the proposed deadline (The Lycos Network, August 3, 1999, Cadmium industry makes last charge against battery ban, accessed March 7, 2001, at URL http://ens.lycos.com/ens/aug99/1999L-08-03-02.html). In its November 2000 Organization for Economic Cooperation and Development (OECD) joint meeting of the Chemicals Committee and the Working Party on Chemicals, however, the EC representatives blocked any attempt to adopt an OECD-wide Ni-Cd battery recycling label (ILZRO Environmental Update, 2000c). In addition to the battery and cadmium industries, manufacturing companies and organizations also expressed reservation about EC's efforts to ban cadmium-containing devices. The American Electronics Association and the Electronics Industries Alliance expressed concern that the ban was being proposed without any analysis of the environmental impacts of replacement materials and processes. The Electric Vehicle Association of Great Britain also opposed the proposed ban, which the association claims could set back the cause of electric vehicles in the EU by 20 years (Advanced Battery Technology, 2000).

In 1991, the U.S. Congress authorized the disposal of the entire stockpile of 2,872 t of cadmium from the National Defense Stockpile. In 2000, the Defense Logistics Agency, which manages the stockpile, sold 319 t of cadmium metal, leaving 807 t still to be sold.

Production

The most common cadmium mineral is greenockite, which is almost always associated with the zinc ore mineral, sphalerite. The average ratio between contained zinc and cadmium in sphalerite is about 400:1 or 0.25%. At least 80% of cadmium output worldwide is estimated to be a byproduct of primary zinc production. The remaining 20% is obtained from secondary sources, such as baghouse dust and the recycling of cadmium products, and from the production of other primary metals. Because of depressed cadmium prices in recent years, the processing of many wastes to recover cadmium has not been economically viable. Thus, cadmium is usually extracted to

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remove it from zinc, lead, or copper production or to recycle cadmium-containing products.

In the United States, only two companies produced primary cadmium during 2000—Big River Zinc Corp., Sauget, IL, and Pasminco Ltd., Clarksville, TN. Both companies used an electrolytic process and recovered the cadmium as a byproduct during the roasting and leaching of zinc concentrate. After removing various impurities, cadmium can be processed to final form by either refining or electrowinning.

The Sauget operation, owned by Korea Zinc Co. Ltd., can produce up to 1,400 metric tons per year (t/yr) of cadmium metal and oxide. About 80% of its concentrate feed was supplied by mines in Missouri and Tennessee, and the remaining 20% was imported, mainly from Canada, Mexico, and Peru (Mining Journal, 1999). The cadmium content of zinc sulfide concentrate is usually between 0.1% and 0.8%. The concentrate is heated in fluidized bed roasters to produce an impure zinc oxide (calcine) suitable for acid leaching. Between 60% and 85% of the calcine, which contains cadmium and other impurities, is volatized with the sulfur dioxide gas generated during the roasting process. Calcine and fume are separated from the gas and collected in waste heat boilers, cyclones, and electrostatic precipitators. The collected calcine dust is combined with the unvolatilized portion of the calcine and dissolved in sulfuric acid at a leaching plant. Generally, manganese dioxide is added to the leaching tank to remove iron and significant amounts of other impurities. These insoluble residues are sold to other smelters for further processing as iron cake. The leachate is sent to a series of cold and hot purification tanks where cadmium and other remaining undesirable metals are removed from the solution. After the first stage of zinc sulfate purification, discharged impurities form a copper cake, which, like the previously captured leach residues, are sold for processing. The bulk of cadmium is precipitated in the second stage of purification, and the remainder is precipitated in a third stage. The cadmium precipitate is filtered and forms a cake containing about 12% cadmium, 25% zinc, and small amounts of other impurities. The cake is then redissolved in sulfuric acid. After two additional acid treatments, a cadmium sponge is produced, which is dissolved in another sulfuric acid bath, and the solution, if sufficiently pure, is passed into electrolytic cells where the cadmium is deposited on cathodes. The resulting more than 99.99%-pure cadmium metal is melted and cast into 50-millimeter (mm)-diameter ball anodes or 250-mm-long sticks or oxidized in a controlled atmosphere to produce cadmium oxide powder. Higher purity cadmium for special purposes, such as for semiconductors, can be produced by vacuum distillation (U.S. Environmental Protection Agency, 1987).

In 1999, Pasminco Ltd. of Australia acquired Savage Zinc Inc. and its parent company, Savage Resources Ltd., also from Australia (Pasminco Ltd., [undated], Welcome to Pasminco, accessed June 1, 2000, at URL http://www.pasminco.com.au). The acquisition extended Pasminco's zinc distribution network into the U.S. market. After the acquisition, Pasminco stated that a plan to triple zinc production capacity at its Clarksville smelter would be postponed (Financial Express, [undated], Pasminco's U.S. smelter expansion plan put on hold, accessed May 3, 2000, at URL http://www.financialexpress.com/fe/daily/19990904/fco04016p.html). In 2000, most concentrate for the Clarksville smelter was supplied by local mines owned by Pasminco and ASARCO Incorporated. When more favorable market conditions develop, Pasminco may expand the smelter. If the capacity of the smelter is increased, domestic production will need to be augmented by imported zinc concentrate, most likely from the newly opened Century Mine in Australia. Increased zinc production could affect cadmium production at the Clarksville smelter, which at present can produce up to 500 t/yr.

The amount of cadmium that is recycled is difficult to estimate for a number of reasons. For example, cadmium from baghouse dust generated at lead and copper smelters enters the primary cadmium production circuit at zinc refining operations and may or may not be included in reported production statistics for primary cadmium metal. Although the reported amount of cadmium produced from the recycling of Ni-Cd batteries is fairly accurate, there are no firm data on the amounts of cadmium recovered from other sources such as electric arc furnace dust, electroplating wastes, filter cakes, sludges, and other cadmium-containing materials. Electric furnace dust, which contains about 0.05% cadmium, is recovered only because it is mandated by environmental regulations; cadmium prices were so depressed in 2000 that the processing of furnace dust for any other purpose was not economically feasible.

In 1995, International Metals Reclamation Co. Inc. (INMETCO), a subsidiary of the International Nickel Co., began reclaiming cadmium from spent batteries at its Ellwood City plant northwest of Pittsburgh, PA. The $5 million high-temperature metal recovery plant addition, built by Davy International Ltd., was the first facility of its kind in the world. It is capable of processing more than 2,500 t/yr of spent Ni-Cd batteries. Cadmium recycling at the facility thus far has been practical only for Ni-Cd batteries, some alloys, and dust from electric arc furnaces. The most difficult aspect of Ni-Cd battery recycling is the collection of spent batteries. Large industrial batteries, containing 20% of the cadmium used for batteries, are easy to collect and are recycled at a rate of about 80%. The remaining 80% of the cadmium used in batteries goes into small consumer Ni-Cd cells and batteries, which for the most part are usually discarded with municipal solid wastes. Therefore, voluntary industry-sponsored collection programs and Government agencies are devising ways to improve the collection of these small batteries. Economies of scale are very important, and the larger a recycling operation, the lower its unit cost is likely to be. Several different collection programs have been developed by INMETCO to meet the needs of battery manufacturers and the numerous consumers, firms, organizations, and agencies that use many diverse products, such as power tools, cordless phones, and personal computers (Industrial Heating, 2000). Rechargeable Battery Recycling Corp. (RBRC) operates the "Charge Up to Recycle!" program, established in 1995, which has organized a multifaceted collection program to collect rechargeable consumer batteries. The RBRC generates revenue for the program by licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. The "Charge Up to Recycle!" program contains several key elements that are specified both in EPA regulations (40 CFR part 273), Federal law (The Mercury-Containing and Rechargeable Battery Management Act of 1996), and in various State laws. These elements include uniform battery labeling, removability from appliances, national network of collection systems, regulatory

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relief to facilitate battery collection, and widespread publicity to encourage public participation. For that purpose, RBRC has undertaken an extensive public education campaign and has established several recycling programs in the United States, such as the Retail Recycling Plan (8,500 participants), the Community Recycling Plan (300 enlisted), and the Business & Public Agency Recycling Plan (1,000 enrolled) (Hugh Morrow, President, International Cadmium Association, written commun., 2001). The RBRC program has about 30,000 collection sites in the United States and Canada, including many at the outlets of major participating retailers. Most of the industrial wet Ni-Cd batteries were recycled through collection programs in which producers of industrial batteries collect and send their spent batteries to INMETCO. A smaller portion of industrial batteries was collected and shipped by various environmental organizations (Bleakney, 1998).

The process of cadmium recovery from industrial and consumer sealed batteries, both of which contain about 15% cadmium by weight, differs only in the manner of battery preparation. Processing of industrial batteries consists of draining the sodium hydroxide electrolyte, cutting the tops off the batteries, and separating the nickel and cadmium plates. Small batteries must be handsorted because only newer batteries are color coded and very few of them carry bar codes, making optical scanning and other automated sorting very difficult.

The cadmium plates from the industrial batteries and the small batteries, from which the plastic casing has been removed in INMETCO's patented thermal oxidizer, are charged into a cadmium recovery furnace. In the furnace, carbon is added as a reductant. The charge is heated and the cadmium is distilled, then collected in a water bath. The final products, called Cadmet shot, are small flattened discs, 4 to 6 mm in diameter, to facilitate handling and to reduce erratic rolling, and have a purity of greater than 99.95% cadmium, some as high as 99.999% cadmium. Cadmet is drummed, weighted, assayed, and shipped to Ni-Cd battery manufacturers for reuse in new batteries, but may also be used in the manufacture of corrosion-resistant coatings or in the manufacture of cadmium-containing stabilizers, alloys or pigments.

In addition to the pyrometallurgical process for recycling cadmium, in which cadmium vapor is collected and then solidified by condensation or oxidation, there are hydrometallurgical cadmium recycling processes as well. In these wet chemical processes, batteries are dissolved in strong acids, then subjected to selective precipitation or ion exchange reactions to separate cadmium compounds from nickel and iron compounds.

Although secondary production has been increasing at about 6% per year and most likely will increase even faster in the future, worldwide primary production will remain basically unchanged for the next few years. Any future increases in domestic production of virgin cadmium will likely come from the Crandon/Rhinelander zinc-copper deposit in northeastern Wisconsin. Its development will depend on the zinc market and on Nicolet Minerals Co., a wholly owned subsidiary of Rio Algom Mining Corp., acquiring some remaining permits from the Wisconsin State Government. Nicolet's proposal of a future mine near the headwaters of the Wolf River, however, is opposed by those who feared the pollution of underground water and altered water levels of nearby lakes caused by pumping of water to keep the shafts dry. The deposit contains an estimated 62 Mt of ore grading 5.6% zinc, 1.1% copper, and 0.01% to 0.23% cadmium (Skillings' Mining Review, 1978). Sphalerite from one particular stratigraphic sequence, the Skunk Lake unit, consistently had the highest cadmium values, averaging 0.09% cadmium (Lambe and Rowe, 1987). Pyrite is ubiquitous throughout most of the deposit. Development of the deposit would include the building of a 2-Mt-capacity mill with an annual production of between 200,000 t and 300,000 t of zinc concentrate and about 20,000 t combined copper-lead concentrate (Metal Bulletin, 1996).

Environmental Issues

Despite being toxic in high concentrations of soluble or respirable forms, dermal contact with cadmium metal results in negligible absorption. However, prolonged exposure to high concentrations of the respirable and soluble forms of cadmium is known to have toxic health effects and adverse environmental impacts. Inhaled cadmium fumes or fine dust are much more readily absorbed than ingested cadmium. Repeated exposure to excessive levels of dust or fumes can have irreversible effects on kidneys and on lungs, producing shortness of breath and emphysema. Because of these potential adverse effects, occupational exposure to cadmium in the United States is regulated by the Occupational Safety and Health Administration (OSHA). OSHA's permissible limit for cadmium exposure through inhalation is 5 micrograms per cubic meter of air breathed (Golden Artist Colors, [undated], Will cadmium always be on the palette?, accessed March 7, 2001, at URL http://www.goldenacrylics.com/cadmiums.htm). Similarly, strict air and water emission limits on cadmium as well as land disposal restrictions on the metal are in effect in the United States and other countries. In the United States, any cadmium-containing waste that leaches more than 1 milligram per liter is considered hazardous waste. Any discharge of cadmium chemicals above a specific threshold level into navigable waters is subject to reporting requirements. The Reference Dose for cadmium in drinking water is 0.0005 milligrams per kilogram per day (mg/kg/d) and in food is 0.001 mg/kg/d (U.S. Environmental Protection Agency, [undated], Cadmium and compounds, accessed March 7, 2001, at URL http://epa.gov/ttnuatw1/hlthef/cadmium.html).

The four main environmental and human health concerns involved with Ni-Cd batteries are occupational exposure, manufacturing emissions and wastes, product use, and product disposal. Because most of the environmental and health problems involved in the production of Ni-Cd batteries can easily be controlled, recent regulations have focused on disposal options. Basically, only four disposal options are available—composting, incineration, landfilling, and recycling. The first two options are not practical; landfilling was the most frequently used alternative and recycling was the one most preferred by the industry and environmentalists. Because most cadmium is produced as a byproduct, mainly of zinc production, restrictions on the use of cadmium in batteries could increase the amount of unprocessed cadmium that is disposed in landfills by zinc producers. Therefore, an effective collection and recycling system for spent batteries would probably protect the environment more than a ban on cadmium in batteries.

Consumption

The USGS does not collect consumption data on either

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cadmium metal or cadmium compounds. Apparent consumption of cadmium metal in the United States is calculated by the USGS from production, trade, and stock changes. Apparent consumption in 2000 increased by nearly 9%, compared with that of 1999. Estimated consumption of cadmium by end use in 2000 was as follows: batteries, 75%; pigments, 12%; coatings and plating, 8%; stabilizers for plastics and similar synthetic products, 4%; and nonferrous alloys and other uses, 1%.

Cadmium metal has a low melting temperature, good electrical conductivity, excellent corrosion resistance in alkaline and saline environments, and the ability to improve the mechanical properties of other metals. Therefore, cadmium metal is commercially used mainly as a corrosion-resistant coating on steel, aluminum, and other nonferrous metals, especially where low friction or low electrical resistivity is needed. Cadmium metal is also added to some nonferrous alloys to improve properties such as strength, hardness, wear resistance, castability, and electrochemical behavior. All cadmium compounds are made from cadmium metal and are primarily used in batteries, pigments, ultraviolet light and weathering stabilizers, and semiconductor applications.

Although cadmium consumption for batteries has been growing steadily for more than 15 years, other cadmium markets, such as pigments, stabilizers, coatings, and alloys, are regarded as mature because they are not expected to grow; in fact, some of the markets have already started to decline. Consumption of cadmium for these dispersible and dissipative applications probably will continue to decline because of increasingly stringent environmental regulations, concerns of manufacturers about long-term liability, and the development of less toxic substitutes. Use of organic cadmium compounds as stabilizers in polyvinyl chloride (PVC) continues to decline since the barium-cadmium stabilizers used in the past can now readily be substituted by barium-zinc, calcium-zinc, or organo-tin stabilizers. Consumption patterns of cadmium compounds varied significantly among countries because of differences in environmental regulations, industrial development, natural resources, and trading patterns. In the United States, Ni-Cd batteries provided the power for three-fourths of the most common portable products, such as cordless telephones, portable household appliances, power tools, battery-powered toys and hobbies, and emergency and remote area power. It is estimated that there are more than 450 million cordless electronic products in the United States.

The consumption of cadmium in batteries could receive a boost from manufacturers of hybrid electric vehicles and providers of telecommunications in remote areas. Although preference for Ni-Cd batteries over other kinds of batteries in hybrid vehicles has not been indisputably established due to environmental restrictions, application as a power source for telecommunications in remote areas holds considerable promise for future cadmium use. Compared to traditional valve-regulated lead acid batteries, the Ni-Cd batteries have longer life, are more reliable, require lower maintenance, have unlimited shelf life, and have the lowest life cycle cost. Replacement and new production of these batteries for telecommunications could translate into an annual requirement of about 2,000 t, or over 10% of the current world's production (Vigerstol, 1998). One of the most promising applications from the cadmium industry's perspective is the use of cadmium telluride solar cells to convert sunlight into electricity and the use of Ni-Cd batteries to store that electrical energy for remote power systems. Consumption for this application could be as high as 5,000 t/yr (Hugh Morrow, President, International Cadmium Association, oral commun., 2001).

A wide variety of cadmium sulfide-based compounds are used as yellow, orange, and red pigments for plastics, glasses, ceramics, enamels, and artists' colors. Organic alternatives still cannot match many of the popular properties of cadmium pigments, especially color brightness, opacity, and processability. One of the more promising noncadmium colorants is a cerium sulfide developed in France (American Metal Market, 1997). Cadmium pigments are particularly well suited for applications requiring high temperature or high-pressure processing or applications where other pigments will readily degrade. Cadmium carboxylates, such as laurate and stearate, are used as ultraviolet light and weathering stabilizers for PVC. The finished PVC product usually contains no more than 0.2% cadmium. The cadmium is locked into the polymer matrix and has extremely low leachability (Donelly, 1996).

Prices

As the byproduct of other metals production, cadmium is not subject to the normal supply-demand dynamics of most metals. The inelastic supply-demand situation associated with byproduct commodities invariably leads to volatile pricing, and such has been the case for cadmium over the past 20 to 30 years. Until the late 1980s, cadmium was used mainly in pigments and alloys. After the Ni-Cd battery was developed, the battery market expanded by 20% per year, and the price of cadmium increased to $9.10 per pound by March 1988. With the exception of 1995, the 1990s were marked by a steady decline in cadmium prices due to tightening regulatory controls and thus reduced consumption in some traditional cadmium markets such as pigments, stabilizers, and coatings. In addition, recycling of cadmium batteries has also led to the availability of secondary cadmium. Cadmium prices remained at historically low levels in 2000. As world supply tightened toward the end of year, however, prices for high purity cadmium (99.99%) began to inch upward. Reduced primary production, offsetting increased secondary cadmium output, and continued moderate demand in spite of regulatory concerns led to a balanced world cadmium market in 2000. Despite increased supply, the price for cadmium in the United States began to increase at the end of 2000 (table 1).

Current Research and Technology

A relatively new process for secondary production of cadmium from recycled Ni-Cd batteries was developed in the past 5 years by a German firm, ACCUREC GmbH. The new process, know as Vacuum Thermal Recycling, is the first ultralow emission process that can be installed modularly with capacities of between 500 t/yr and 5,000 t/yr. The vacuum process has advantages because under vacuum all elements evaporate at a significantly lower temperature and the hermetic construction prevents contamination by escaped gases. A charge of about 500 kilograms of spent batteries is inserted in a quartz pipe that is vacuum-sealed and is heated to 100° C to 150° C. After all water has evaporated, the charge can be heated to the operating temperature of about 750° C. Following the inclusion of various additives, the cadmium oxide is reduced

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and evaporated. The metal vapor is then water-cooled in a metal condenser, where it forms a metallic cadmium block (Wehye and Melber, 2000a).

In rare welcome news for the cadmium industry, a Princeton University study found that, under certain conditions, some organisms grow better when they contain cadmium. According to the study, cadmium joins a group of elements (such as selenium, nickel, tungsten, and iron) that can have either a toxic effect or perform an essential biological function, depending on environmental conditions. The enzymes that help interconversion of carbon dioxide, essential for respiration in animals and fixation of carbon dioxide during photosynthesis in plants, require a metal, which is usually zinc. However, under conditions where zinc is scarce, some marine organisms produce a cadmium-specific carbonic anhydrase. For example, the marine diatom *Thalassiosira weissflogii* produces a cadmium-specific carbonic anhydrase when it is starved of zinc and cannot make enough of the zinc-requiring carbonic anhydrase (ILZRO Environmental Update, 2000a).

A University of Arkansas research team has found a way to replace dimethylcadmium with cadmium oxide to form nanocrystals, which are used in applications such as special electronics and optoelectronic devices. Dimethylcadmium is a toxic chemical that is unstable at room temperature and explosive at higher temperatures. The researchers discovered that from a base of safer cadmium oxide they can make a variety of nanocrystals incorporating several different materials (Business Week, 2001a).

At the University of California at Berkeley, new forms of cadmium selenide crystals have been developed for use in the manufacture of solar panels. The new crystals facilitate electron flow and could boost efficiency to over 20%, compared to far more expensive existing solar cells (Business Week, 2001b).

Outlook

Historically low prices, limited growth in many mature cadmium markets, and pending environmental restrictions are factors that must be considered in forecasts for the cadmium industry. Zinc mining companies that produce cadmium as a byproduct, have begun to regard the metal as a cost rather than a credit. The cost of producing cadmium, which is difficult to determine apart from zinc, probably has exceeded the sale price in some cases. The immediate future of the cadmium industry rests largely with the Ni-Cd battery market, which is the only market that continues to grow, especially in certain sectors, such as power tools and telecommunication uses. Following declines in recent years, the coatings and pigments markets for cadmium have stabilized and are not expected to erode any further in the future. The stabilizers and alloys markets, however, are expected to diminish and eventually close due to substitution by cadmium-free products. However, several new applications, such as telecommunications, electric and hybrid electric vehicles, remote area storage systems, and solar cells could become significant cadmium markets.

The future of the cadmium market will be determined by the extent to which industry is able to fully implement the collection and recycling of cadmium products. The success of new cadmium recycling technologies is critical not only in battery markets, but also for other principal end-use products. Recycling of industrial Ni-Cd batteries, which retain nearly 100% of the market for emergency lighting, alarms, and power tools, and have a production rate that is growing by about 3% per year, has begun and is expanding. The rechargeable battery industry has been growing significantly in recent years and is expected to continue growing well into the 21st century. State and Federal mandates now require manufacturers and battery resellers (companies that use Ni-Cd batteries in their products) to recycle rechargeable batteries and prohibit commercial users from discarding them in municipal solid waste. Further increases in the recycling rate for rechargeable batteries will depend on the cooperation of consumers, which in turn will reflect the convenience of collection systems (Rechargeable Battery Recycling Corp., [undated], The non-profit company that recycles Ni-Cd rechargeable batteries, accessed April 25, 2000, at URL http://www.rbrc.org). According to a survey conducted by the RBRC, 95% of Americans own cordless electronic products, but just 16% recycle their power sources (American Metal Market, 1999). Because spent Ni-Cd batteries are 100% recyclable, battery collection and recycling systems that are economically viable as well as environmentally sound may be possible. Collection and recycling rates must continue to increase to reassure regulators and the general public that any human health or environmental risks associated with cadmium will be well managed. Improved recycling of Ni-Cd batteries is also necessary to forestall a ban on the use of cadmium in Europe. Recycling of cadmium products other than batteries, however, will be considerably more difficult. The proper disposal of discarded plastics, obsolete electronic parts, incinerator residues, and municipal sewer sludge—all of which often contain low levels of dispersed cadmium—remains a difficult problem. Moreover, even though increased cadmium recycling is environmentally desirable, it will have only a limited effect on the amount of cadmium in the environment: According to recent estimates, just 2% of cadmium present in the environment is attributable to all uses of the metal. Most of the cadmium released into the environment results from the burning of fossil fuels and from iron and steel production (Metal Bulletin, 1999).

U.S. collection and recycling programs for small rechargeable batteries are expected to expand further, and has now moved into Canada. The Portable Rechargeable Battery Association has helped to enlist the participation of county and municipal governments, hospitals, and fire departments. Spent Ni-Cd, nickel-metal hydride, lithium-ion, and small sealed lead-acid batteries are now all being collected under the program (Greg Broe, Portable Rechargeable Batteries Association, oral commun., 2001). According to the RBRC, about 1,700 t of rechargeable batteries was recycled in 2000. Assuming an average cadmium content of 15% per battery, more than 255 t of cadmium was recycled rather than discarded in landfills (Greg Broe, Portable Rechargeable Battery Association, oral commun., June 2001).

References Cited

Advanced Battery Technology, 2000, EVA says ban could kill market: Advanced Battery Technology, v. 36, no. 7, July, p. 4.

American Metal Market, 1997, Color me cadmium.....or Neolor: American Metal Market, v. 105, no. 144, July 28, p. 7.

———1999, Most Ni-Cd batteries wind up in landfills, trade group claims: American Metal Market, v. 107, no. 223, November 18, p. 7.

Bleakney, Russ, 1998, The collection and processing of spent nickel cadmium batteries in North America and INMETCO's role, in International Nickel Cadmium Conference, 8th, Prague, Czech Republic, September 21-22, 1998, Proceedings: Brussels, Belgium, International Cadmium Association.

Digitized by Google

Business Week, 2001a, Innovations: Business Week, no. 3722, March 5, p. 30B.
———2001b, Making solar cells on the cheap: Business Week, no. 3722, March 5, p. 100.
Donelly, P.J., 1996, Cadmium compounds as stabilizers for PVC, in Sources of cadmium in environment, OECD Cadmium Workshop, Saltsjöbaden, Sweden, October 16-20, 1995, Proceedings: Brussels, Belgium, European Commission, p. 276-280.
ILZRO Environmental Update 2000a, Cadmium reported to have essential biological function under certain oceanic environments: International Lead Zinc Research Organization, Inc., v. 10, no. 5, May, p. 2.
———2000b, Debate continues on PBT classification for metals: International Lead Zinc Research Organization, Inc., v. 10, no. 8, August, p. 3.
———2000c, European Commission rejects OECD Ni-Cd battery recycling label: International Lead Zinc Research Organization, Inc., v. 10, no. 12, December, p. 2.
———2000d, USEPA proposes revision to the aquatic life criteria for cadmium: International Lead Zinc Research Organization, Inc., v. 10, no. 9, September, p. 2.
———2001, Global organizations issue new directives on chemicals in the environment: International Lead Zinc Research Organization, Inc., v. 11, no. 2, February, p. 1.
Industrial Heating, 2000, Reclaiming alloy and ingot from nickel-based batteries: Industrial Heating, v. 67, no. 8, August, p. 16.
Lambe, R.N., and Rowe, R.G., 1987, Volcanic history, mineralization, and alteration of the Crandon massive sulfide deposit, Wisconsin: Economic Geology, v. 82, no. 5, August, p. 1204-1238.
Metal Bulletin, 1996, Crandon Mining plans to develop Rhinelander deposit: Metal Bulletin, no. 8096, July 15, p. 6.
———1999, Battery scrap collection "key to prevent Cd ban": Metal Bulletin, no. 8378, May 24, p. 17.
Mining Journal, 1999, Korea Zinc completes Big River takeover: Mining Journal, v. 326, no. 8373, April 12, p. 12.
Price, L.J., 1998, Cadmium and lead recovery in Florida from rechargeable battery product stewardship, in International Seminar on Battery Waste Management, 10th, Deerfield Beach, FL, October 27, 1998, Proceedings: Boca Raton, FL, Florida International Seminars, Inc., p. 1-10.
Skillings' Mining Review, 1978, Zinc-copper resources of Wisconsin: Skillings' Mining Review, v. 67, no. 12, March 25, p. 15-20.
U.S. Environmental Protection Agency, 1987, Cadmium emission from cadmium refining and primary zinc/zinc oxide smelting—Phase I technical report: U.S. Environmental Protection Agency, 212 p.
Vigerstol, Ole, 1998, NiCd batteries for telecommunications, in International Nickel Cadmium Conference, 8th, Prague, Czech Republic, September 21-22, 1998, Proceedings: Brussels, Belgium, International Cadmium Association.
Wehye, Reiner, and Melber, Albrecht, 2000, Vacuum thermal recycling of used batteries, Battery recycling meeting: Singapore, May 8-10, 2000.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Cadmium. Ch. in Mineral Commodity Summaries, annual.
Cadmium. Ch. in Minerals Yearbook, annual.
Cadmium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

American Metal Market.
Cadmium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Engineering and Mining Journal.
International Cadmium Association technical publications.
Metal Bulletin (London).
Mining Journal (London).
Platt's Metals Week.

TABLE 1
SALIENT CADMIUM STATISTICS 1/

(Metric tons, cadmium content, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production of metal 2/	1,530	2,060	1,240	1,190	1,890
Shipments of metal by producers 3/	1,310	1,370	1,570 r/	1,020 r/	1,580
Exports of metal, alloys, scrap	201	554	180	20	312
Imports for consumption, metal	843	790	514	294	425
Stocks of metal, Government, yearend	2,030	1,870	1,680 r/	1,130 r/	807
Apparent consumption of metal	2,250	2,510	2,100 r/	1,850 r/	2,010
Price, average per pound, New York dealer 4/	1	1	0	0	0
World, refinery production	18,900	19,500	19,200 r/	19,700 r/	19,700 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
3/ Includes metal consumed at producer plants.
4/ Price for 1- to 5-short-ton lots of metal having a minimum purity of 99.95% (Platt's Metals Week).

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TABLE 2
U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

Year	Cadmium sulfide 1/	Other cadmium compounds 2/
1999	64	604
2000	42	417

1/ Includes cadmium lithopone and cadmium sulfoselenide.
2/ Includes oxide and plating salts (acetate, carbonate, nitrate, sulfate, etc.).

TABLE 3
SUPPLY AND APPARENT CONSUMPTION OF CADMIUM METAL 1/

(Metric tons)

	1999	2000
Industry stocks, January 1	729	893
Production	1,190	1,890
Imports for consumption of metal, alloy, scrap	294	425
Shipments from Government stockpile excesses	554 r/	319
Total supply	2,760 r/	3,530
Exports of metal, alloys, scrap	20	312
Industry stocks, December 31	893	1,200
Consumption, apparent 2/	1,850 r/	2,010

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Total supply minus exports and yearend stocks.

TABLE 4
CADMIUM INDUSTRY STOCKS, DECEMBER 31 1/

(Metric tons)

	1999		2000	
	Metal	In compounds	Metal	In compounds
Metal producers	800	W	1,130	W
Compound manufacturers	93	15	73	17
Distributors	W	(2/)	W	W
Total	893	15	1,200	17

W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

TABLE 5
U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1999 Quantity (kilograms)	1999 Value	2000 Quantity (kilograms)	2000 Value
Cadmium metal: 2/				
Argentina	--	--	66,000	$68,000
Austria	--	--	2,800	6,800
Belgium	9,420	$15,000	--	--
Brazil	--	--	784	105,000
Canada	917	19,200	20,300	259,000

See footnotes at end of table.

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TABLE 5
U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1999 Quantity (kilograms)	1999 Value	2000 Quantity (kilograms)	2000 Value
China	--	--	4,980	$56,400
France	2,940	$136,000	171,000	226,000
Germany	332	110,000	2,740	39,300
Hong Kong	--	--	948	83,100
India	2	4,730	--	--
Japan	2,330	113,000	17,000	20,800
Korea, Republic of	67	11,500	504	42,900
Malaysia	--	--	172	3,340
Mexico	2,490	76,900	6,570	180,000
Taiwan	1,040	17,400	--	--
United Kingdom	811	19,500	18,500	50,000
Total	20,400	523,000	312,000	1,140,000
Cadmium sulfide: (gross weight)				
Canada	11,100	4,240	--	--
China	--	--	937,000	509,000
France	--	--	5,840	3,030
Hong Kong	--	--	52,700	27,400
Japan	96,200	24,000	--	--
Philippines	--	--	92,500	48,100
Taiwan	--	--	20,700	19,600
Total	107,000	28,200	1,110,000	607,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes exports of cadmium in alloys and scrap.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF CADMIUM PRODUCTS, BY COUNTRY 1

Country	1999 Quantity (kilograms)	1999 Value	2000 Quantity (kilograms)	2000 Value
Cadmium metal:				
Algeria	3,000	$6,940	--	--
Australia	76,000	26,800	76,900	$30,900
Belgium	60,800	244,000	99,400	329,000
Canada	98,200	461,000	40,200	954,000
China	--	--	35	16,600
France	3,990	4,590	--	--
Germany	--	--	73,100	28,000
Japan	170	28,100	--	--
Kazakhstan	--	--	103	5,140
Mauritania	--	--	10,000	28,700
Mexico	9,300	10,700	85,800	60,000
Netherlands	--	--	21,900	7,060
Peru	17,700	41,300	--	--
Russia	5,000	15,100	16,700	47,900
Spain	20,000	9,700	--	--
United Kingdom	--	--	1,200	5,520
Total	294,000	848,000	425,000	1,510,000
Cadmium sulfide: (gross weight)				
Germany	--	--	54	5,250
Japan	13,800	37,900	43,100	138,000
Russia	26	2,630	--	--
United Kingdom	4,640	54,300	2,270	26,500
Total	18,400	94,800	45,400	169,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 7
CADMIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria e/	75	75	75	75	75
Argentina	40	45	34	-- r/	-- 2/
Australia	639	632	585 r/	462 r/	552 2/
Belgium	1,579	1,420	1,318	1,400 e/	1,400
Brazil e/	300	300	300	300	300
Bulgaria e/	250	250	200	200	200
Canada	2,537	1,272	1,361	1,390	1,390 p/
China e/	1,570	1,980	2,130	2,150 r/	2,200
Finland 3/	648	540 e/	520	500 e/	550
France	92	309	177 r/	195 r/	200
Germany	1,150 e/	1,145	1,020	1,100 e/	1,000
India	271	298	300 e/	300 e/	300
Italy	296	287	328	360 r/	350
Japan	2,344	2,473	2,337	2,567 r/	2,472 2/
Kazakhstan e/	800	1,000	1,450	1,061 2/	1,060
Korea, North e/	100	100	100	100	100
Korea, Republic of	501	570	1,178 r/	1,791 r/	1,180
Macedonia e/	(4/)	(4/)	(4/)	(4/)	(4/)
Mexico 5/	784	1,223	1,218 r/	1,352 r/	1,350
Namibia 6/	14	2	--	-- e/	--
Netherlands	603	718	739	731 r/	730
Norway	274	290	270 e/	211 r/	200
Peru	405	474	474	480 e/	480
Poland	--	22	-- r/	-- r/	--
Romania e/	5	4	-- r/	-- r/	--
Russia e/	730 2/	790	800	900	925 2/
Serbia and Montenegro e/	79 2/	80	80	15	15
Spain	307	301	196	--	--
Thailand	385	238	238 r/	238 r/	240
Turkey	42	89	69	60	30
Ukraine e/	25	25	25	25	25
United Kingdom 7/	541 e/	455	440 e/	547 r/	500
United States 7/	1,530	2,060	1,240	1,190	1,890 2/
Total	18,900	19,500	19,200 r/	19,700 r/	19,700

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ This table gives unwrought production from ores, concentrates, flue dusts, and other materials of domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by a footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, Ware, the United Kingdom) and from Metal Statistics (published jointly by Metallgesellschaft AG, of Frankfurt am Main, Germany, and World Bureau of Metal Statistics). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. This table includes data available through May 11, 2001.

2/ Reported figure.

3/ Excludes secondary production from recycled nickel-cadmium batteries.

4/ Less than 1/2 unit.

5/ Excludes significant production of cadmium oxide and cadmium contained in exported concentrates.

6/ Tsumeb Smelter closed in April 1998.

7/ Includes secondary.

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CEMENT

By Hendrik G. van Oss

Domestic survey data and tables were prepared by Nicholas Muniz, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

As the binding agents in concrete and mortars, hydraulic cements are key construction materials. Hydraulic cements are those that can set and harden under water and are dominated by varieties that can be loosely grouped as portland cement and masonry cement. Only portland and masonry cements are covered in this report. In 2000, U.S. production of portland and masonry cements, combined, continued a multiyear trend of new annual records with a 2.2% increase to 87.8 million metric tons (Mt) (table 1). Output of clinker—the unground intermediate product of cement manufacture—increased by almost 3% to a new record of 78.1 Mt. The United States continued to rank third in the world in overall hydraulic cement output, behind China (about 36% of the world's total) and India; world output was about 1.6 billion metric tons (Gt).

Domestic consumption of cement again reached new record levels, but the growth in 2000 was significantly slower than annual rates over the period 1995-99 and reflected weakness in the overall U.S. economy. Apparent consumption of cement in 2000 (calculated as production plus imports minus exports minus the change in yearend stocks) rose only by 1.5% to 110.5 Mt; it had grown by 5.2% in 1999 (table 1). Cement consumption measured as sales to final domestic customers increased by 1.0% to 109.7 Mt (table 9); the growth rate was only one-fifth of that of the previous year. The large production shortfall in 2000, as in previous years, continued to be met by imports of cement and clinker but at a slightly lower level overall; it was the first decline since 1992. Exports, in contrast, rose in 2000 but remained an almost insignificant component of total cement commerce. Cement prices were virtually unchanged during the year. The total ex-factory value of annually reported cement sales to final domestic customers rose by 2.6% to $8.3 billion (table 1). If the unit value of the cement is applied to the larger, monthly-based sales tonnages in table 9, the total rises to $8.6 billion but is an increase of only 1.2%. By using typical cement-in-concrete mix ratios, the delivered value of concrete, excluding mortar, in the United States was estimated to be at least $37 billion in 2000.

Portland and masonry cements are based upon portland cement clinker, made up mostly of calcium silicates and manufactured by controlled high-temperature burning in a kiln of a measured blend of calcareous rocks (usually limestone) and, as needed, lesser quantities of siliceous, aluminous, and ferrous materials. The clinker is finely ground together with a small (generally about 5%) amount of calcium sulfate in the form of gypsum and/or anhydrite to make (straight) portland cement. Straight portland cement can be sold directly to concrete manufacturers or other customers, converted at the cement (or concrete) plant into a blended (portland) cement product of similar properties by adding other cementitious or pozzolanic (siliceous materials requiring added lime to become cementitious) extenders, or mixed with such plasticizing materials as ground limestone or lime to make masonry-type cements used in mortar. A full listing of cement varieties included within the portland cement designation as used in this report is given in table 16. Although included within the portland cement designation in this report, data showing blended cements separately from the other forms of portland cement are available within the monthly cement reviews of the

Cement in the 20th Century

In 1900, the hydraulic cement industry of the United States was less than a century old, and until that year, its output had been dominated by natural and pozzolanic cements. Portland cement had been manufactured domestically since only the early 1870s, and by 1900, its output of 1.46 million metric tons had just exceeded that of natural and pozzolanic cements (1.22 million tons, combined) for the first time. In 1900, hydraulic cement production was valued at $19.4 million. Cement was being manufactured at 114 plants, 50 of which produced portland cement. Total world cement production was probably only about 60 million tons, of which 44 million tons was in Europe. Cement consumption in the United States totaled 3.07 million tons in 1900, or about 24 kilograms per person. About 13% of the total cement consumed was imported, mostly from Europe. Most of the consumption was for concrete blocks and mortars.

In 2000, production of cement reached 87.8 million tons, valued at about $6.9 billion; about 95% of output was portland cement. Output was from 116 plants, most of which were owned by European-based multinational corporations. Consumption of cement totaled 109.7 million tons, or about 380 kilograms per person; the 22-million-ton production deficit was met by imports from around the world. The dramatic increase in production and consumption during the course of the century reflected increasing diversity of use of concrete in large office buildings, houses, roads, bridges, sewers, and dams. Except for major disruptions during the Great Depression and World War II, production had risen fairly continuously, reaching about 30 million tons by 1928 and again by 1947, surging through the 1950s onwards to about 78 million tons in 1973, fluctuating at lower levels over the period 1974-93, and resuming steady growth thereafter. World production in 2000 totaled about 1.6 billion tons, almost 60% of which was from Asia; China and India together contributed 40%.

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U.S. Geological Survey (USGS) Mineral Industry Surveys series, starting with January 1998. Excluded from the portland and masonry categories and from this report are such hydraulic cement varieties as pure pozzolan cements [especially so-called slag cement, which is simply ground granulated blast furnace slag (GGBFS)] and aluminous cements. These cements contain no portland cement clinker and, cumulatively, make up only a small fraction of the U.S. cement market.

The bulk of this report incorporates data compiled from USGS annual questionnaires sent to individual cement and clinker manufacturing plants and associated distribution facilities and import terminals (some independent of U.S. cement manufacturers). For 2000, responses were received from 143 of 144 facilities canvassed, which included all producers, covering 100% of actual production and more than 99% of sales. For 1999, responses were received from 139 of 141 facilities canvassed, including all but 1 small producer, and covering more than 99% of total U.S. production and sales. Two tables (9 and 10) of this report are based on monthly shipment surveys of the cement-producing companies and importers, for which the response rate was 100% for both years. Trade data are from the U.S. Census Bureau. The world hydraulic cement production data (table 23) were derived from data collected by USGS country specialists from a variety of sources.

As in previous years, significant tonnage differences exist between the annual (survey) sales totals for portland cement listed in tables 1 and 11 through 16 and the larger monthly-survey-based totals listed in tables 9 and 10. The differences, amounting to 5.3 Mt in 1999 and 4.0 Mt in 2000, likely represent imported cement handled by certain terminals acting independently of the manufacturing plants; although incorporated within the monthly data set, some of these terminals' sales appear to be missing from the annual survey. Accordingly, the monthly data are believed to be the more complete measure of cement consumption. The equivalent discrepancy for masonry cement is insignificant, likely because little of this material is imported.

Where required to protect proprietary information, State data are combined within groupings or districts, generally corresponding to census districts or subsets thereof. To provide additional market information, some major cement-producing States have been subdivided along county lines; the county breakouts are given in table 2.

There were three significant ownership changes within the U.S. cement industry in 2000. In June, Australian-owned CSR America, Inc. (owner of Miami, FL, cement producer CSR Rinker Materials, Inc.) purchased Florida Crushed Stone Co., which operates a dry plant at Brooksville, FL. Two months later, Greek producer Titan Cement S.A. purchased the assets of Anglo American plc's subsidiary Tarmac America, Inc., thereby gaining full control of Roanoke Cement Co. in Virginia (in which Titan was already a joint-venture partner) and Pennsuco Cement Co. in Florida. Titan also owned Essex Cement Co., a New Jersey-based cement importer. By far the most important ownership transfer, however, took place at the end of September, when Cemex S.A. de C.V. of Mexico (CEMEX) announced its purchase of Southdown, Inc., the second largest U.S. cement producer and (hitherto) the largest U.S.-owned cement company. Prior to this purchase, CEMEX's only production facility in the United States was the Balcones Plant (formerly operated under the name Sunbelt Cement Co.) in Texas, and the company owned large import terminals in California and Arizona. With the purchase of Southdown, CEMEX gained control of a dozen more plants spread throughout the country—namely at Brooksville, FL; Charlevoix, MI; Clinchfield, GA; Demopolis, AL; Fairborn, OH; Knoxville, TN; Kosmosdale, KY; Lyons, CO; Odessa, TX; Pittsburgh, PA; Victorville, CA; and Wampum, PA—as well as a number of terminals. The Kosmosdale and Pittsburgh plants were joint ventures with Lone Star Industries, Inc. (25%).

Early in the year, Lafarge, the world's second largest cement producer, launched a well publicized hostile takeover bid for British company Blue Circle Industries, a major rival world and U.S. cement producer. Had it been successful, the merger would have made Lafarge the largest cement producer in the world and the United States. The bid failed when, in May, Blue Circle shareholders rejected Lafarge's bid.

Legislation and Government Programs

Economic Issues.—Government economic policies and programs affecting the cement industry chiefly are those affecting cement trade, interest rates, and public sector construction spending. In terms of trade, the major issue in 2000 remained that of antidumping tariffs against Japan and Mexico and a related voluntary restraint (import price) agreement with Venezuela that were imposed in the early 1990s following complaints in the late 1980s by a large coalition of U.S. producers. On March 6, 2000, the U.S. Department of Commerce (DOC) released its determination for the (eighth) review period covering August 1997 to July 1998; the dumping margin for the period was set at 45.84% (Southern Tier Cement Committee, 2000a). Pursuant to a World Trade Organization agreement, which became effective in 1995 and which required a sunset review after 5 years to determine the necessity of continued antidumping tariffs, a review was begun in mid-1999 of the antidumping remedies imposed on Japan, Mexico, and Venezuela. On June 27, 2000, the DOC issued the results of its part of the sunset review (as to whether dumping would continue or resume if tariffs were removed). The determination was that dumping would continue/resume at high margins by all three countries (Southern Tier Cement Committee, 2000b). The second investigation under the sunset review process was conducted by the U.S. International Trade Commission (ITC) and was to determine whether or not dumping, if continued or resumed, would cause injury to the U.S. cement industry. On October 5, the ITC concluded its investigation, determining, on a majority vote, that injury would occur if dumping resumed or continued by Japan and Mexico. Accordingly, the antidumping remedies against these two countries would be maintained for another 5 years. However, in a unanimous vote, the ITC terminated the antidumping remedy (pricing agreement) against Venezuela (Southern Tier Cement Committee, 2000c). The ruling on Mexico was a surprise to some analysts who had speculated that continued injury to the industry from Mexican cement imports would be difficult to prove following the withdrawal in late 1999 of Southdown, Inc., a major proponent of the original tariffs, from the industry coalition that was supporting the continuation of the antidumping remedies. Southdown had cited the strong U.S. cement market conditions in recent years and substantial control of imports by U.S.

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producers as evidence that the tariffs were no longer needed. It was unclear whether CEMEX, the main Mexican company targeted by the antidumping order on Mexican cement, would appeal the ITC ruling based on a change of circumstances following its purchase of Southdown.

In terms of Government funding of construction projects, the cement industry had anticipated much higher spending levels in 1999 and 2000 on road and related infrastructure repair and construction as a result of the signing into law in June 1998 of the Transportation Equity Act for the 21st Century (TEA-21). This law authorized $216.3 billion in funding for the 6-year period from 1998 to 2003 for the purpose of upgrading the country's transportation infrastructure. The level of funding exceeded previous spending levels by an average of about 44% per State, and the bill contained substantial funding guarantees. Funding provided for various facets of highways, including new roads and bridges and existing infrastructure upgrades and repair, totals about $173 billion, of which about 95% was guaranteed. Estimates varied as to how much added cement consumption [typically 6 million to 8 million metric tons per year (Mt/yr)] would result from full-level TEA-21 spending, but nowhere near this level of added consumption had materialized as of yearend 2000. It appeared that the impact of delays in State funding (for cofunded projects) and of lag times between project initiation and actual cement consumption was greater than had been anticipated.

Environmental Issues.—Both mining and manufacturing are involved in cement production. As shown in table 6, approximately 140 Mt/yr of raw materials are directly or indirectly mined in the United States to produce cement, and the clinker that is imported converts to another almost 8 Mt/yr of raw materials, albeit mined outside the country. Calcareous feeds, such as limestone, make up about 85% of the raw materials mined by the cement companies themselves; most of the remaining materials are obtained locally as well. In addition, as shown in table 7, the cement industry burns significant quantities of fossil fuels. Most mines and quarries supplying the cement industry are open pit operations. Environmental issues affecting mining of cement raw materials are mostly local and are common to most surface mines; they include potential problems with dust, increased sediment loads to local streams, noise, and ground vibrations from blasting. Of greater concern, however, are the environmental impacts of the cement manufacturing process itself, most of which stem from the manufacture of clinker.

In 2000, U.S. clinker kilns burned about 15 Mt of fossil and/or other organic fuels (table 7). In the debate over climate change, the impact of greenhouse gases on atmospheric warming is a major issue. The most common greenhouse gas is carbon dioxide (CO_2), and fuel combustion and calcination of carbonate (limestone) feed in the clinker kilns both generate large quantities of this gas. Calcination basically follows the equation: $CaCO_3 \rightarrow CaO + CO_2\uparrow$. Although precise determinations of CO_2 emissions by the U.S. industry are unavailable from the companies themselves, reasonable estimates (within 5% to 10%) of the emissions for the industry overall can be made based on certain assumptions as to the composition of the raw materials and fuels consumed and the clinker produced. These assumptions are explained in more detail in the 1999 and earlier editions of this report, but generally, the production of 1 metric ton (t) of clinker releases 0.51 t of CO_2, and the combustion of fuels releases on the order of 0.4 to 0.5 t of CO_2, depending on the types of fuel consumed and the pyroprocessing technology used. Thus, approximately 1 t of CO_2 is released per ton of clinker, and very slightly less (because of the added gypsum) per ton of straight (unblended) portland cement. Based on the clinker production shown in table 5, the U.S. industry released about 77 Mt of CO_2 in 2000. Additionally, U.S. cement plants consumed electricity (table 8) equivalent to about 7 to 8 Mt of CO_2, but this "emission" generally would be assigned to the electrical power industry.

Although dwarfed by the collective CO_2 emissions of powerplants and motor vehicles, the cement industry is one of the largest remaining industrial sources of this gas and is perhaps the largest single industrial source (or possibly second to the iron and steel industry) of CO_2 not derived from the combustion of fuels. Because of this ranking, the cement industry receives more attention concerning its CO_2 emissions than it would like, notwithstanding the fact that its CO_2 emissions are only about 1.5% of the U.S. total (U.S. Environmental Protection Agency, 2001, p. ES-4). The concern of the cement industry with CO_2 continues to be the possibility that the Government, either under the obligations of international environmental treaties or by its own volition, will seek to substantially reduce the cement industry's emissions by such means as the imposition of carbon taxes, the enactment of emissions quotas, or the requirement that low(er) emissions production technologies be used.

As discussed in more detail in the 1999 edition of this report, the Kyoto Protocol, signed at the United Nations Framework Convention on Climate Change held in Kyoto, Japan, in 1997, calls for reductions in CO_2 output by countries to levels substantially below those in 1990, to be achieved by 2012. As of yearend 2000, the U.S. Congress had not ratified the protocol nor had most of the other signatories. To meet its Kyoto Protocol target (7% below 1990 emissions levels), the United States would need to reduce its emissions by 20% or more by 2012 from what they would potentially be at current emissions growth rates. Roughly similar reductions would apply to other countries bound by the protocol. Given that the overwhelming majority of nonagricultural emissions of CO_2 are from the burning of fossil fuels, any major reductions in CO_2 emissions would have to be through proportional reductions in energy consumption, and the economic ramifications of this could be substantial. Most objections to the Kyoto Protocol revolved around the fact that only the so-called developed countries would be bound by it (although all the others would be encouraged to reduce emissions), leaving them at economic disadvantage to countries not so bound. Various proposals for emissions trading, and receiving credit for so-called carbon-sinks, have been debated to reduce the potential economic impacts. In late November, the Sixth Conference of the Parties to the United Nations Framework Convention on Climate Change was held in the Hague (a followup meeting to that in Kyoto in 1997) to discuss these proposals, but no agreement was achieved.

There has been substantial interest in developing precise and auditable inventories of CO_2 and other greenhouse gas emissions to aid emissions reduction strategies. In mid-2000, the Intergovernmental Panel on Climate Change released its so-called good practices methodologies, designed to calculate national emissions levels (Intergovernmental Panel on Climate

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Change, 2000).

For the U.S. cement industry, mandated major reductions in CO_2 emissions could require shutting a number of older plants, especially those operating wet kilns, and/or upgrading plant equipment to more efficient technologies. Upgrading, for various reasons, is already underway at many plants but is an expensive process. Mandated emissions reductions could force plants to burn less carbon-intensive fuel, for example, natural gas rather than coal. Many U.S. cement plants already are able to switch among a variety of fuels, but large-scale shifts of cement plants and other fuel-intensive facilities (e.g., powerplants) to natural gas could lead to local shortages and price increases for that fuel. An alternative emissions-reduction strategy, market permitting, would be to increase the output of blended cements and perhaps allow the addition of small amounts of inert extenders (as bulking agents) in straight portland cement. Either strategy would reduce the clinker (and hence emissions) component of the finished cement, which in turn would reduce total emissions by the cement industry or at least constrain emissions increases if cement demand (and output) grows. A major shift to blended cements could lead to local shortages of suitable pozzolans, as well as increased prices for them. The U.S. concrete industry is itself a significant direct consumer of pozzolans, which are used as a partial substitute for portland cement in ready-mixed concrete and some other concrete mixes. A recent review of CO_2 emissions reduction strategies, focusing on reductions of specific energy consumption, is given in Martin, Worrell, and Price (1999). Cement kilns are considered to be an environmentally benign way of burning a variety of hazardous and nonhazardous wastes, owing to the very high temperatures at which clinker is made and the long residence times of materials in the kiln. A waste fuel that has received recent attention in Europe is bone meal, which has become abundant through the necessity of slaughtering vast numbers of diseased livestock and which, from such contaminated sources, is unusable for most other applications (Whitehorn, 2001).

Another approach to reducing emissions from clinker manufacture is to use a noncarbonate source for some of the CaO in the kiln feed. A process patented by Texas Industries, Inc. (TXI), and known as CemStar, makes use of ferrous (particularly steel) slag as a CaO raw material in the kiln feed. As noted in a review by Perkins (2000), use of CemStar increases clinker output by as much as 10% or more, with commensurate reductions in unit CO_2 emissions. The process has been licensed to a number of plants and is reflected in the steel slag consumption data in table 6.

Other emissions of the cement industry include cement kiln dust (CKD), nitrogen and sulfur oxides (NOx and SOx, respectively), and dioxins and furans. The U.S. Environmental Protection Agency issued regulations concerning these and other emissions from the industry in 1999, but most of these regulations were still under one form or another of review or debate in 2000. Except for CKD (virtually all of which is captured and a majority of which is recycled to the kilns), the cement industry is not considered a major source of these pollutants compared with a number of other industries. The cement industry is nonetheless concerned about new emissions limits and prescribed monitoring methods, namely the degree that they can or cannot be realistically implemented and/or the emissions controlled. Many plants are already improving their burning systems to reduce NOx emissions; a review of methods to do this is given by Wahlquist (2000).

Production

In 2000, cement was produced in 37 States and in Puerto Rico. All of the facilities were in the private sector with the exception of one plant (Dacotah Cement Co.) that was State-owned. At yearend 2000, about 79% of U.S. portland cement output and 85% of its production capacity were foreign-owned, a major increase from the 68% foreign ownership status at yearend 1999 and mostly owing to the CEMEX purchase of Southdown. In addition to the portland and masonry cement plants, there were several grinding facilities that produced GGBFS from unground slag from domestic or foreign sources. When ground, this material (GGBFS) is sold to the cement and concrete industries as a cementitious additive; it is also known as "slag cement," but the use of this term is confusing as it already refers to a specific type of high GGBFS-content blended portland cement. GGBFS plants will not be dealt with in this report except to the extent that their product makes its way into blended cements, and with respect to the fact that all or most of them could grind clinker instead, should market conditions so warrant.

Although, technically, there were no new (greenfields) plant openings in 2000, a facility in Florida that had commenced clinker production in late December 1999 had its first output and sales of portland cement in January 2000 and reached full capacity production levels (clinker and cement) later during the year. One small grinding facility that had in recent years only been operated as a terminal resumed grinding on an intermittent basis. New plants are planned or are under construction in Colorado, Florida, Missouri, New York, and Texas.

Following the startup of clinker production at yearend 1999, Florida Rock Industries, Inc., had its first production and sales of portland cement from its new 0.68-Mt/yr Newberry, FL, plant in January 2000, a project reviewed by Cohrs (2001). The facility reached full output levels after several months of ramp-up operations. Suwannee American Cement Co. received some of its environmental permits to construct a greenfields plant near Branford, FL (Portland Cement Association, 2000b).

Many existing plants had expansion projects completed during the year or which were within 1 to 2 years of completion. A few of the larger projects will be mentioned here. Ash Grove Cement Co. was replacing the two wet kilns at its Chanute, KS, facility with a single dry kiln of about 1.5 Mt/yr capacity; the work was expected to be completed by mid-2001 (Ash Grove Cement Co., 2001). Blue Circle was adding a new kiln line at its Calera, AL, plant, with a completion date anticipated for 2002 (World Cement, 2000). The company also commissioned a new slag grinding mill at its Detroit, MI, clinker-grinding plant. Early in the year, Holnam, Inc., fired up its newly constructed second kiln line at its Midlothian, TX, plant. The new line doubled the plant's existing capacity to 2 Mt/yr (Arthur, 2000). Essroc Cement Corp. was planning to expand the capacity of its Speed, IN, plant by 75% by converting its long dry kiln to short dry technology. The work was anticipated to be completed around yearend 2001 (International Cement Review, 2000a). At yearend, Holnam broke ground for a new 2,000 Mt/yr dry kiln to replace the existing pair of wet kilns at its Holly Hill, SC, plant. The kiln was expected to come online

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in mid-2003. Holnam was also constructing a new 1.9 Mt/yr dry kiln line to replace the three existing wet lines (total capacity 0.77 Mt/yr) at its Florence, CO, facility; the new line was targeted to start production in early to mid-2001. At yearend, Holnam announced its decision to proceed with a project to build a 4 Mt/yr greenfields cement plant in St. Genevieve County, MO. This would be the largest single kiln line in the country (Cement Americas, 2001). Lehigh Portland Cement Co. was replacing the four long dry kilns at its Union Bridge, MD, plant with a new, single, dry precalciner kiln. The new line was due to be fired in early 2001 (Barzoloski, 2000). At midyear, Lone Star completed the conversion of its Greencastle, IN, wet kiln to semidry technology, thereby almost doubling its capacity to 1.17 Mt/yr. This was the first semidry line in the country (Mining Engineering, 2001). In August, RC Cement Co. brought online a new finish mill at its Signal Mountain Cement Co. subsidiary in Tennessee; the project's new 0.72-Mt/yr kiln line was due to be fired up in early 2001, at which time the existing pair of wet kilns would be shut down (Maranzana, 2000). RC's subsidiary River Cement Co. was planning to expand the capacity of its Selma, MO, plant by about 0.4 Mt/yr (Portland Cement Association, 2000a). Late in the third quarter, Southdown, Inc. (prior to its takeover by CEMEX), completed the kiln line upgrade of the Kosmos Cement plant in Louisville, KY; announced in 1999; the plant is a joint ventured with Lone Star. Work on the new finish mill at TXI's Midlothian, TX, was completed late in the year and the company expected to have the plant's new kiln fired in January 2001. This will increase the plant's capacity to about 2.5 Mt/yr (International Cement Review, 2000b).

Portland Cement.—Portland cement was manufactured in the United States in 2000 at a total of 115 plants out of 116 claiming clinker grinding capacity (the remaining plant produced only GGBFS). There were also two portland cement plants in Puerto Rico. Seven of the portland-cement-producing facilities were only grinding plants (that did not produce their own clinker); one of these was operated only intermittently during the year, and several also ground slag in addition to clinker. The regional distribution of these plants, cement production and capacities, and yearend cement stockpiles are listed in table 3.

In 2000, production of portland cement rose by 2.4% to 83.5 Mt, a new record but still well below total consumption (table 9). Further, the production was slightly enhanced (0.27%) by the added production day (2000 was a leap year). The production shortfall continued to be met by imports (tables 18-22). As shown in table 3, portland cement production increases were noted in all but 10 districts. The decreases were all in districts accessible to imported cement. The top five producing States, in descending order, continued to be California, Texas, Pennsylvania, Michigan, and Missouri.

Cement (grinding) capacity increased by 6.0% to 103.4 Mt as a result of upgrades at several plants; large increases were reported in a dozen districts, and only four districts showed decreases. Capacity utilization was high virtually everywhere, although it fell slightly (to 80.7% utilization) for the country overall. Where the annual utilization rates appeared to be low or had fallen significantly, the cause was generally the coming on-stream of additional capacity, which was fully counted but not fully used during the year. Florida remained a case in point, with a new plant starting its grinding mill in January 2000 (clinker production commenced at yearend 1999) and upgrades coming on-line at other facilities. The capacity utilization figure is understated because it is calculated using only the production of portland cement, whereas the grinding capacities reported by the plants include that for masonry cement. If masonry cement production (table 4) is included, national grinding capacity utilization in 2000 recalculates to 84.9%, compared with 88.1% in 1999. Given the fact that reported capacities take into account shutdowns only for routine maintenance, the capacity utilization rates shown are likely close to full practical operational levels.

The 2000 district and national annual grinding capacities exceeded, sometimes by large amounts, the corresponding clinker production capacities listed in table 5. This is owing to a number of factors. Some districts have dedicated grinding facilities that import all of their clinker. It is generally easier and cheaper for an integrated plant to add grinding capacity than to add clinker capacity. Extra grinding capacity allows a plant to quickly increase product output and to change cement formulations by the expedient of importing clinker and/or cementitious additives. The exceptionally large excess grinding capacity in Michigan in part reflects restricted cement-shipping capabilities of one plant during the winter—all of its cement must be made (ground) and shipped during the open-water months.

The grinding capacity declines shown in a few districts may simply represent temporary mill shutdowns during upgrade projects or the permanent retirement of obsolete grinding equipment. In some years, declines may also reflect the transfer of some grinding capacity to nonclinker applications where the reporting company chose not to consider it as available for cement.

Yearend 2000 stockpiles of portland cement were 11% higher than at yearend 1999; although this change affects the apparent consumption statistics in table 1, it has little significance for the cement industry itself. Shifts in stockpiles can result from buildups or drawdowns related to maintenance and upgrade shutdowns of mills, changes in sales volumes, interruptions to delivery schedules, and the conversion of one type of cement to another higher tonnage type (such as portland converted to blended cement).

Although the sales of various types of portland cement are listed, split out, on table 16, data are not collected on the actual production of the different varieties of portland cement. However, it is likely that the production, for most types, is at least somewhat proportional to the sales in table 16, both in relative percentage and absolute tonnage terms, after adjustment for sales of imported cement (see tables 18-22). The import adjustment can only be approximate, because import tariff numbers only allow differentiation of clinker from hydraulic cement, and within hydraulic cement, differentiation only among gray portland (this would include most of the table 16 listings), white portland, aluminous cement, and "other" hydraulic cement. In terms of the gray portland imports, it may be assumed that the majority qualifies as Types I or II (imports into southern California include a lot of Type V). An import adjustment for white cement is made difficult because of problems with the import data (see the "Values" subsection under the "Consumption" section below). Finally, imports feed stockpiles, not just sales. The import cautions notwithstanding, it can at least be stated that production of Types I and II (or

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hybrids thereof) accounted for about 90% of total portland cement output.

Portland cement producers in the United States ranged from those having a single, perhaps very small, plant to large, multiplant corporations having in excess of 10% of total U.S. capacity. The ranking of these companies in terms of production and capacity is complicated by how one defines the term "company;" some entities are subsidiaries of common parent corporations and some plants are jointly owned by two or more companies. If companies having common parents are lumped under the larger subsidiary's name, and if the joint ventures are apportioned, the top 10 companies at yearend 2000, in descending order of production, were Holnam, CEMEX (Southdown), Lafarge, Lehigh, Ash Grove, Blue Circle, Essroc, Lone Star, RC Cement, and TXI. Together, these accounted for 72% and 69% of total U.S. production and production capacity, respectively, and all except Ash Grove and TXI were foreign-owned as of yearend.

Masonry Cement.—Production of masonry cement (including plastic and portland lime cements) fell by 1% to 4.3 Mt in 2000 (table 4), following an almost 10% increase the previous year. Unlike portland cement, masonry cement production was virtually identical to its reported domestic consumption, and very little of that consumed was imported (table 9). The data in both tables 4 and 9, however, underrepresent true production and consumption levels of masonry cement, because it is common for masonry cement (particularly the portland lime variety) to be made at the job site itself, from purchased portland cement and lime. There are no data on this jobsite activity, but it is likely to be substantial. The reported production decline reflects lackluster demand during the year (see "Consumption" section below) and cold-weather-induced work delays towards yearend. In 2000, all but 5% of the masonry cement was reported by cement companies as having been made directly from clinker rather than starting from a finished portland cement. This ratio has not varied much in recent years.

Clinker.—Table 5 lists district-level information on clinker production, capacity, capacity utilization, and yearend stockpiles. Output of clinker increased by 2.8% to 78.1 Mt in 2000, yet another record. As with cement, clinker production in 2000 reflected a 0.3% increase owing to the 1-day longer leap year. The increase was widespread, with only a few districts (Illinois, Kentucky, Mississippi, and Tennessee; Arizona and New Mexico; and northern California) showing declines, and most of these were small. As in 1999, clinker was produced by a total of 111 integrated cement plants, operating 201 kilns. Two of these plants and kilns were in Puerto Rico. About 70% of the plants used dry-process kiln technology. Two facilities operated both wet and dry kilns, and one facility completed its kiln conversion during the year from wet to semidry technology (listed as dry in table 5).

California, Texas, Pennsylvania, Missouri, and Michigan, in descending order, remained the top five clinker-producing States in 2000. Combining companies as much as possible under common ownership, the top 5 companies had 49% of total U.S. clinker production and capacity, and the top 10 companies had about 72% of both. The top 10 companies, in descending order of production, were CEMEX (including Southdown), Holnam (remained first in capacity, however), Lafarge, Lone Star, Lehigh, Ash Grove, Essroc, Blue Circle, RC Cement, and TXI.

Apparent clinker capacity increased by 4.0% to 89.3 Mt/yr; as with production, the capacity statistic benefited from the additional workday in 2000. Capacity utilization fell slightly to 87.5% (from 88.5% in 1999), but there continued to be only very few districts that showed utilization rates below 85%. The low rate in Indiana was due to a kiln conversion (upgrade) shutdown for part of the year. With few exceptions, the capacity utilization rates depict an industry at full practicable production levels nationwide.

Annual clinker capacity and capacity utilization data are sensitive to reporting errors related to the classification of kiln downtimes. For each kiln, apparent annual capacity is calculated as the reported daily capacity times the "expected working year," which is the full year (366 days in 2000) minus the number of days that the kiln was shut down for routine maintenance. Emergency shutdowns, scheduled shutdowns for plant upgrades, and those for slow market conditions are not counted, except to the extent that they overlap the days planned for routine maintenance. Typically, one or two outages, totaling 1 to 4 weeks, are scheduled for annual routine maintenance, and this work mostly revolves around replacement or repair of the refractory brick linings in kiln and other pyroprocessing equipment. Company interpretations vary, however, as to what should be counted as routine maintenance, and those interpretational differences affect the length of the expected working year and hence the calculated annual capacity. This downtime uncertainty or sensitivity means that small changes in regional annual capacity or capacity utilization have little, if any, statistical significance. This differs from the grinding (cement) capacity data noted earlier, which are directly reported by the plants. The daily clinker capacities listed in table 5 should be viewed with caution as they are particularly sensitive to propagation of rounding errors.

Within the above constraints, average plant clinker capacity in 2000 was 0.82 Mt/yr, up by 3.7%, and average kiln capacity was 0.45 Mt/yr, up by 4.4%. Plants operating only dry (including one semidry plant) process kilns produced 75.5% of the total clinker (table 7), those operating wet kilns accounted for 22.5% of the clinker, and the two plants that operate both types of kilns contributed the remainder. The dry kiln contribution in 1999 was 73.7%.

Yearend 2000 clinker stockpiles totaled 5.3 Mt, up by 1.5 Mt, but the significance of this is uncertain. Clinker stocks are generally built up ahead of planned kiln shutdowns, most but not all of which are held in the winter months. Some clinker is also imported. Nevertheless, the yearend increase in 2000 is in line with reported monthly clinker production increases late in the year (and in all other months except May) combined with an 11% drop in portland cement sales in November and a 17% drop in December. The stockpile increase, combined with an increase in production, is consistent with the decline of 0.8 Mt in clinker imports for the year (table 22).

Raw Materials and Energy Consumed in Cement Manufacture.—Nonfuel raw materials used for cement manufacture may be divided into materials used to make the clinker and those added subsequently in the grinding phase (finish mill) to make the cement itself. The differentiation is primarily of environmental interest; materials used to make clinker are burned in the kiln and are associated with various chemical changes and emissions; those used in the finish mill

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are merely comminuted. Table 6 lists these materials as well as the amount of imported (foreign) clinker ground. About 1.7 t of nonfuel raw materials are needed to make 1 t of clinker, and the ratio also approximately holds to make portland cement (provided that the foreign clinker used to make cement is also back-converted to raw materials). Limestone or other calcareous materials account for about 87% of the total raw materials required. The mass ratios among various major raw materials were essentially the same for 2000 and 1999. The listing of materials under headers like "Calcareous" and "Siliceous" is to some degree artificial because many of the raw materials supply more than one oxide.

The clinker versus cement differentiation of nonfuel raw materials is subject to reporting errors, as this was not requested prior to the 1998 survey and some plants remain unaccustomed to it. Accordingly, some of the increases in 2000 may simply reflect improved reporting rather than a net change in true consumption. Additionally, some materials may be inconsistently classified from year to year or among plants. For example, one plant's limestone might be another's cement rock; likewise with clay and shale and among the several ferrous slags. Furthermore, some materials are generally not routinely fully measured by the plant, most notably CKD, where the component automatically recycled to the kiln is generally unmeasured. Accordingly, the CKD consumption listed in table 6 (clinker column) is substantially too low. Increasing environmental interest in CKD may lead the industry to begin measuring this material more completely in the future.

Among the siliceous raw materials, some of the pozzolans appear to be out of balance with the sales (as a proxy for production) of blended cements listed in table 16. This is true especially for GGBFS, consumption of which is much too high for the sales of the appropriate blended cement. The explanation for this is that most of this slag was not consumed by the cement industry to make blended cements but was used as a grinding aid in States that allow an addition of a minor amount (up to about 3%) of GGBFS within Type I portland. However, the amount of GGBFS listed in table 6 is perhaps only 10% of the true consumption of this material by, ultimately, the concrete (especially ready-mixed) producers, who buy GGBFS directly from slag processors and blend it as a partial portland cement substitute into their concrete mixes. Likewise, the amount of fly ash listed in the table 6 cement column is but a small fraction of the roughly 9 Mt/yr of this material purchased directly by the concrete industry for use as a cement extender (American Coal Ash Association, 1999). It should be reiterated that table 6 reflects consumption by the cement producers, not the concrete manufacturers. The large increase in steel slag consumption (for clinker) in table 6 appears to reflect the increasing popularity of the CemStar process developed by TXI, as discussed earlier.

Table 7 lists the consumption of fuels by type of kiln process. Many cement plants are able to switch among a variety of primary fuel types, and many routinely burn a mix of fuels. It is difficult to analyze changes in the ratios among fuels on a national basis, save that the high costs of petroleum-based fuels and natural gas in 2000 led to widespread shifts back to coal and increased use of solid and liquid wastes. The decline in use of waste tires is surprising but may reflect unreported problems with environmental permits held or sought by specific plants. It could also represent data omissions or misinclusion of tires in the "Solid" waste rather than "Tires" category.

As in past years, dry plants produced the majority of the clinker and consumed the majority of fuels (although less fuel per ton of clinker), with the exception of wet process consumption of liquid waste fuels. High production costs associated with the wet kiln process made the cost savings achievable through use of liquid wastes (which the plants are paid to take) very attractive, and the very long residence times in the kilns made for environmentally efficient burning of this material.

Table 8 lists the consumption of electricity by the cement industry, differentiated by process type. As expected, dry process plants had a higher average unit electricity consumption that wet kilns, reflecting the complex array of fans and blowers associated with modern dry kilns. The average unit consumption for dry plants increased slightly in 2000, possibly reflecting the inclusion of one semidry plant that was converted from wet technology during the year. The large increase in unit consumption by plants operating both wet and dry kilns is of little significance, as it represents only two plants. The increase listed for grinding plants, which follows a decrease in 1999, may reflect increased output of GGBFS from some of these plants. Slag-processing plants have higher unit electricity consumption levels than do cement mills because slag is harder to grind and is ground finer than clinker.

Consumption

Apparent consumption of cement is listed in table 1 and rose by 1.5% in 2000 to 110.5 Mt. Although apparent consumption is a standard statistic for comparing consumption of various commodities, the measure of consumption preferred by the cement industry for its market analyses (because the data are available monthly and are sourced directly from the cement companies) is that of cement sales or shipments to final customers. These monthly data are listed totaled for 1999 and 2000 in tables 9 and 10. Consumption (sales) in 2000 of portland and masonry cement rose by 1.0% to 109.7 Mt. The definition of "final customer" is left to the reporting cement producer, but is generally understood to include concrete manufacturers, building supply dealers, construction contractors, and the like. The monthly data are collected in terms of the destination of sales (location of final customer, i.e., consumption by State), and by State or country of origin (manufacture). Although the monthly reports differentiate between portland cement and (portland-based) blended cement, both are included in the term "portland cement" in this report (including table 9).

Tables 11 through 16 list various annual survey data on or derived from shipments of cement reported by cement producers and import terminals. Some of the data, especially those in tables 12 and 13, look superficially similar to the data in tables 9 and 10, but there are important differences between the two data sets, particularly for portland cement. Tables 9 and 10 show the larger totals, and these data are believed to be more complete (especially regarding imported cement) and thus a better measure of true consumption levels. Tables 9 and 10 also show the true location of the sales (customers) for the cement; however, the cement could have been sourced elsewhere. In contrast, the regional data in tables 12 through 16 simply reflect the location of the reporting facilities, not their customers nor

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necessarily where the cement was manufactured.

Examination of the data for Michigan and Ohio will illustrate the interpretational difference between the two data sets. Michigan consumed 3.5 Mt of portland cement in 2000 (table 9), but Michigan producers shipped almost 5.8 Mt (table 12) to final customers, not necessarily all in Michigan. Michigan was thus a net exporter of cement. Ohio consumed 3.9 Mt of portland cement, but its producers (and terminals) shipped only 1.2 Mt (table 12). Ohio was thus a net importer of cement. Nonproducing States like New Jersey import all of the cement they consume (table 9).

National Consumption.—In 2000, portland cement consumption grew by only 1.1% (compared with 5.0% in 1999) but still achieved a new record of 105.3 Mt (table 9). The imported cement component of this fell by 2.5% to 21.9 Mt; the decline was mainly because of domestic production increases, but imports still were about 21% of total consumption. However, the cement import volumes understate the importance of imports, because the country also brought in 3.8 Mt of clinker (table 22), equivalent to about 3.9 Mt of portland cement, so the true import dependence for portland cement in 2000 was closer to 25%. Masonry cement consumption declined by 0.5% to 4.3 Mt from the record level of 1999. The import component of this was only about 1%.

Because cement is a key construction material, growth in cement consumption reflects trends in construction spending. Overall construction spending levels increased by 2.1% in 2000 (relative to revised 1999 data) to $706.9 billion (constant 1996 dollars), according to U.S. Census Bureau data quoted by the Portland Cement Association (2001). Within this total, residential construction grew by 2.1% to $323.7 billion, of which single-family dwellings accounted for $204.8 billion, up by 1.1%. Despite continued very low mortgage rates, the residential construction growth rate in 2000 was modest compared with the 6% level seen in 1999 and reflected a generally slowing economy; much of the growth was in residential improvements rather than new units. Private nonresidential construction grew by 3.6% to $179.7 billion, powered by a 12.0% increase in office construction to $47.6 billion. This performance likely reflects the long lead times on orders placed in 1999 or earlier. Industrial construction fell by 6.2% to $27.4 billion and followed a 17.2% drop in 1999. Public sector construction spending was essentially stagnant (down by 0.2%) in 2000 at $151.8 billion. Public building construction increased by 2.8% to $70.4 billion. The important road construction component of public spending fell by 3.6% to $45.2 billion, a disappointment given the anticipated increase in spending related to TEA-21 funding, and the 8.8% (revised) spending increase in 1999. The explanation, in part, was that a higher than anticipated percentage of TEA-21 work during 2000 was for repairs rather than for more concrete-intensive new construction. Further, the slowing general economy was apparently hurting State revenues and hence State contributions to projects that involved joint State and Federal funding sources.

In contrast with recent years, the growth rate in overall construction spending in 2000 was higher than that, in tonnage terms, of portland plus masonry cement consumption. In the latter half of the 1990s, an increase in "penetration rate" (tons of cement consumed per million dollars of construction spending) was seen more or less each successive year. The improved penetration rate was generally credited to promotional efforts by the cement industry, in some years aided by moderate (relative to other construction materials) cement price increases. For example, in 1996, $1 million in construction spending "bought" 147.9 t of cement, and in 1999, $1 million (in 1996 dollars) "bought" 156.7 t of cement. Despite the virtually stagnant cement prices in 2000 (see "Values" subsection that follows), the penetration rate per $1 million (1996 dollars) declined to 155.2 t. The reasons for the decline are unclear, but probably include a combination of factors. Ignoring speculation on construction spending data accuracy (caused by to reporting delays, for example) and the likelihood of revisions to the 2000 inflation rates, major factors could be lag times in construction schedules relative to payment reporting, construction design (i.e., use of concrete versus competing construction materials), construction categories (e.g., single family versus multiple family dwellings versus roads versus factories, etc.), and type of work (e.g., concrete-intensive new construction versus less concrete-intensive repairs). Regarding the type of work, it might be speculated that, in a slowing economy, new construction might be deferred in favor of repairs to existing structures. Another factor, although difficult to quantify, is the fact that even the USGS monthly cement surveys do not capture 100% of the cement imports, but these missing imports are being consumed nonetheless. If this missing material amounted to just 1 Mt more in 2000 than in 1999, the penetration rate for 2000 would be unchanged from that in 1999. Yet another factor, also difficult to quantify, is that the true total consumption of hydraulic cement in the United States would include that of cementitious or pozzolan extenders bought directly by the concrete producers. These extenders have been mentioned in the raw materials discussion in the "Production" section and also will be discussed in the "Types of Portland Cement Consumed" subsection that follows; the tonnages involved (especially pre-1998) are not known with certainty, but would likely be in the range of 7 Mt/yr to 12 Mt/yr for the period 1996-2000. Finally, total construction spending involves many material and other costs (e.g., labor) besides those for cement or concrete.

Table 9 lists consumption of portland cement by State, and the general origins of the (total) cement consumed. About half of the States showed consumption declines, although many of these were small and likely would have registered a net increase for the year but for cold-weather-induced declines almost nationwide in November and December. Consumption increases were maintained in most of the strong-performing States of recent previous years, although strong increases (of 0.1 Mt or more) were seen only in California, Colorado, Florida, Nevada, and Virginia. Texas, usually a strong performer, managed to eke out a modest increase courtesy of the northern half of the State. Overall, in contrast with recent years, consumption in the southeastern Atlantic and Gulf Coast States was generally weak throughout the year, notably southern Texas (except during the summer). Several of the Rocky Mountain States, notably Utah, showed a slowdown in consumption, although Nevada remained very strong. Consumption grouped by census district is listed in table 10. In terms of portland cement, the 10 largest consuming States, in declining order, were California, Texas, Florida, Ohio, Illinois, Michigan, Georgia, Pennsylvania, Arizona, and New York. These combined had 53.5% of the U.S. total consumption.

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Consumption of masonry cement also declined in about half of the States, but most of the declines were small. As noted in the "Production" section, data for masonry cement sales to final customers (table 9) underrepresent true consumption because it is common for masonry cement to be mixed from components at the job site rather than being brought in as a finished product. Also, the data exclude the output of a small number of small masonry cement blending plants, which are treated instead as final customers for portland cement. The very small (reported) consumption decline is likely because of to late year cold weather construction delays compared with the warmer 1999 winter.

Table 11 lists portland cement shipments to final customers in terms of transportation method. As in previous years, bulk deliveries by truck directly from plants or via terminals continued to dominate deliveries to customers. In contrast, railroad and waterborne transport were the most important methods of shipping cement from plants to terminals.

Values.—Tables 12 through 14 list mill net values provided by the plants and import terminals for their total shipments to domestic final customers of gray portland cement, white cement, and masonry cement. Because value data are highly proprietary and some companies express misgivings about providing value data of any type, values are not requested for shipments by individual types of portland cement. However, the tonnages shipped, by type, are reported (table 16). For the value of total shipments, no distinction is made between bulk and container (bag) shipments; however, container shipments would be expected to have higher unit values. Regional values for white cement have been lumped with those for gray portland cement, with the exception of the national total for white in table 14. Fewer than 10% of respondents to the 2000 survey declined to provide mill net value data—a modest improvement from the 1999 survey. Where value data were not provided, values supplied by plants in the same market area were averaged and applied as an estimate.

Mill net values for integrated plants can be defined as the (sales) value at, or free on board (f.o.b.), the manufacturing plant, including any packaging charges but excluding any discounts and shipping charges to the final customers. For independent terminals, particularly import terminals, the equivalent statistic sought would be the terminal net value. In the case of imports, this would essentially represent the cost, insurance, and freight (c.i.f.) value of the imports plus unloading and storage costs plus the terminal's markup.

Because the values listed in table 12 incorporate more than one type of portland cement, in both bulk and bag shipments, and some overall estimates, readers are cautioned that the values listed should be considered to be estimates, even though they are presented unrounded. Indeed, the mill net values are better viewed as price indices for cement, suitable for crude comparisons among regions and during time. Most especially, the unit value data cannot be viewed as actual shopping prices for cement. The data for portland cement are assumed to be dominated by bulk sales of the Types I and II varieties.

The average mill net value of portland cement in 2000 was $77.34 per ton, up by only 0.2%— a change of no statistical significance. Combined with a 2.4% increase in shipment tonnage (table 12), the total value of shipments rose by 2.6% to $7.8 billion. The same average unit value applied to the larger portland sales tonnage in table 9 yields a total value of $8.1 billion, up by 1.4%. The lower percentage increase in the value of the table 9 sales reflects the inclusion therein of a higher tonnage of (inexpensive) imported material than in table 12. Although the tonnage of imported cement grew by 0.7% in 2000, the unit value of the imports fell by 2.2% to $49.57 per ton (tables 18-22). Another constraint on portland cement prices continued to be that ready-mixed concrete companies (customers), for cost and performance reasons, were using a substantial fraction of cementitious or pozzolanic extenders in their mixes, which they would blend themselves, and were thus buying less straight or blended portland cement than they would have otherwise. By comparison with the average customs value (comparable to mill net plus, possibly, shipping to the export terminal) of imported gray portland cement, which was $35.50 per ton (table 20), and which is a rough indicator of sales prices in foreign countries, U.S. sales prices were very high by world standards. This made the United States a very attractive export target for many foreign producers.

Table 13 lists masonry cement sales and values in terms of the location of the reporting facilities. The average unit value of sales rose by 4.1% to $107.42 per ton and total sales rose by 2.6% to $459 million ($465 million for the volume in table 9). It should be noted, however, that the mill net values for masonry cement contain more component estimates than those for portland cement, and for a number of respondents, the masonry cement mill net values appear to have been reported on a bulk-equivalent basis instead of being inclusive of bagging charges.

Table 14 is a summary of cement unit values for the country overall. The data for white cement should be viewed with caution because there are only a few producers and importers of this product, and a significant share of white cement sales to final customers is as (marked up) resales by gray cement companies. Additionally, white cement includes a larger component of relatively costly package shipments, of imported material, and of estimates overall. Thus, the 4% unit mill net value decrease in 2000 to $159.45 per ton, if real, may not be statistically significant. A discussion of prices for imported white cement is given in the "Foreign Trade" section that follows.

The only data for domestic delivered prices for cement are those for Type I portland (per short ton) and masonry cement (per 70-pound bag) published monthly by the journal Engineering News-Record. The data represent a survey of customers, which most likely are ready-mixed concrete producers for portland cement and building supply depots for masonry cement, in 20 U.S. cities. The 20-city average delivered price in 2000 for Type 1 portland cement converts to $88.79 per metric ton, up by 1.7%, and ranged by only $1.29 per ton during the year. In contrast to some recent years, prices declined in the fourth quarter from their summer highs, reflecting cold-weather-related construction activity declines in the winter. The $12.18 difference between the Engineering News-Record average price and the average mill net value for gray portland cement in table 14 is an indicator of the approximate average delivery charge for bulk cement. This was significantly higher than the $10.86 per ton delivery differential in 1999 and likely reflects, at least in part, the higher fuel costs in 2000. District variations in mill net values in table 12 do not parallel very well the variations among Engineering News-Record prices for comparably located cities, possibly reflecting

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local transportation and related variables and the fact that the mill net regionality (table 12) reflects the location of the survey respondent, not the customer. The Engineering News-Record 20-city average for masonry cement in 2000 was $6.23 per bag, which literally converts to $196.21 per ton and which was a 26% increase from the price in 1999. The average price and the price shift both greatly exceed the $107.42 per ton (up by 4%) mill net value shown in tables 13 and 14. The large differences for masonry cement would seem excessive, even accounting for a large component of packaging, handling, and (higher) delivery charges, and may reflect price reporting inaccuracies in either or both surveys.

Cement Customer Types.—Data on (portland) cement usage is collected on the basis of the types of customers to whom the cement is sold (table 15) rather than the direct application itself. The distinction is that a given customer, although classified in one category, may in fact have used the cement in more than one way. The data in table 15, as with values, are approximations. The main reason for this is that the surveys request more details (user categories) than many respondents are able to provide. Although much improved in recent years' surveys, there remain a number of companies or plants that either do not track their customers by user type at all or do so only broadly. A persistent problem is that of overlap of categories, the most common example of which is in cases where the customer is a ready-mixed concrete producer that is also engaged in road paving. The dilemma for the respondent is whether to assign the sales to the "Ready-mixed concrete" or to the "Contractors—road paving" subcategory on the form or whether to attempt a split. Further, for several user categories, the subset "Other" commonly gets used as a catch-all instead and is thus overused. Where estimates are made, either by the companies themselves or by the USGS, there is a bias towards the major usage categories; the minor categories are, therefore, likely underrepresented. As with the shipment data in table 12, the regional divisions in table 15 are the locations of the respondents, not the customers.

Notwithstanding these limitations, a number of comments on cement user types in 2000 can be made. As in past years, the dominance of ready-mixed concrete producers in the cement market is very evident. Ready-mixed concrete companies purchased almost 75 Mt of portland cement in 2000, or almost 74% of total sales, although there is undoubtedly significant overlap with the almost 5 Mt assigned to road paving contractors (table 15, footnote 5) and with the 1 Mt assigned to the "Government and miscellaneous" category. Compared with the respective levels in 1999, the ready-mixed tonnage in 2000 was up by 3.4%, the road paving category was down by 18%, and the two combined increased by 1.8%. Because the ready-mixed plus road paving combination would be expected to closely track the 2.4% increase in total (all categories) portland cement sales, some of the ready-mixed tonnage would be better assigned to the road paving category. That the road paving tonnage is likely too low is further supported by the 3.6% decline in road and highway construction spending noted earlier. A transfer of just 0.9 Mt, either all from the ready-mixed category or split 50-50 with the "other or unspecified" contractor subcategory, to the road paving category would shrink the road paving tonnage decline for the year to 3.6%. But this would not be statistically justified given that the overall error range in the table 15 data likely exceeds this adjustment amount significantly. Further, the tonnages do not reflect some of the imported cement used by ready-mixed concrete companies and road pavers.

Portland cement sales to concrete product manufacturers increased by 10.4% to 13.5 Mt, with sales to brick and block manufacturers up by 9.1% to 6.1 Mt; precast concrete companies, up by 22% to 3.1 Mt; and pipe manufacturers up by 8.2% to 1.7 Mt (table 15, footnote 4). These growth rates exceed those for building construction noted earlier, but this may not be suspicious given the large component of value added in building construction. Overall consumption by contractors fell by almost 13% to about 7.1 Mt, with large percentage declines seen in all the specific categories, not just road paving (table 15, footnote 5). These declines, again, seem to be out of step with the construction spending levels noted earlier but in part may reflect consumption of imported cement not captured by the annual survey. Sales to building materials dealers fell by 16.3% to 3.5 Mt, which would appear to be out of phase with the increased spending levels for residential construction; the decline probably, at least partially, reflects incomplete reporting.

The general category "Oil well, mining, waste" lumps minor categories that are prone to underrepresentation. Portland cement sales to customers engaged in oil well drilling were up by 41% to 1.2 Mt (table 15, footnote 6), although the rate of change is out of line with the almost 80% increase, to 1.0 Mt, in sales of oil well cement (table 16). The discrepancy is hard to evaluate because the user tonnage is likely underreported, and ordinary types of portland cement (e.g., Types I, II), which tend to get assigned to major use categories, can be used for shallow oil wells in lieu of specialized oil well cements. A large increase in such sales was expected, however, given higher crude petroleum prices and drilling levels during the year. There was an almost 48% increase in the average weekly Baker Hughes (oil and gas drilling) rig count for 2000 (Oil & Gas Journal, 2001). Reported sales to mining companies fell by 28%, but the data are likely incomplete and subject to large relative errors because of the small tonnages involved. A large decrease in 2000, however, was expected given generally depressed metal commodity prices during the year and anecdotal accounts of mine closures and layoffs. Cement is used by mining companies as an agglomeration agent for heap leaches and in concrete for machinery foundations and for backfill of underground excavations.

Types of Portland Cement Consumed.—Sales to final customers of varieties falling within the broad definition of portland cement are listed in table 16. In 2000, Types I and II, combined, accounted for 88% of total portland sales, a typical proportion though slightly lower than in 1999. As noted in the introduction, the annual survey tonnages (e.g., table 16) are smaller by several million tons than those derived from the monthly surveys. It is believed that most of the "missing" tons are imports, and it is known that the great majority of cement imports are of Type I and II portland. Accordingly, the entries for Types I and II and the grand totals in table 16 could be augmented by about 5 Mt and 4 Mt in 1999 and 2000, respectively. Minor augmentations would also be justified for the white cement and Type V categories. Reported sales of Type V portland cement jumped by 46% in 2000, but much of this increase can be accounted for by a reclassification of some Type I and II material made and sold in California based on its

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actual chemical performance (Type V cements exhibit high sulfate resistance).

Blended cement sales in 2000 grew by 8.6% to 1.3 Mt, representing 1.3% of total portland cement sales, about the same as in 1999. The 2000 sales (table 16) of blended cements are slightly higher than those derived from the monthly surveys (1.2 Mt and 1.2% of total portland plus blended sales), but the difference appears to be of little statistical significance. Overall, the proportion of total blended to total portland cement sales have remained virtually unchanged during the past several years, despite anecdotal evidence that concrete producers (particularly of ready-mixed product) have increased their use of cementitious extenders during this period. Evidently, although blended cement paste is becoming more popular with the concrete producers and their customers for cost and performance reasons, the concrete companies find it cheaper to do their own purchasing of extenders and their own blending rather than purchasing blended cements from the cement companies.

Notwithstanding similar total blended cement sales tonnages during the years, the ratios among specific types of blended cement have been variable. In 2000, sales of blends containing natural pozzolans fell by almost 16% (relative to levels in 1999) to 0.2 Mt; those of blends containing GGBFS rose almost by 29% to about 0.4 Mt; sales of blends with fly ash rose by 27% to 0.4 Mt; and sales of miscellaneous blended cements (e.g. containing CKD or silica fume) dropped by 9% to 0.3 Mt. In contrast, sales in 1999 (relative to 1998) of natural pozzolan blended cements declined by 19%; blends with GGBFS were up by 81%; those with fly ash were down by 27%; and those with miscellaneous pozzolans rose by 47%. For the 2000 blended cement sales, the tonnages listed are in line with the raw materials consumption (for cement rather than clinker) shown in table 6, except for blends with GGBFS and "Other pozzolans." The comparisons assume a typical pozzolan content in blended cement of 15% to 30% and that none of the pozzolan consumption in table 6 was for masonry cements. For GGBFS, the consumption for cement listed in table 6 is two to three times the amount needed to make the blended cement sold (table 16). The excess represents material used in the finish mills as a grinding aid; this is permitted within Type-I portland designations in some States provided that the slag content in the cement does not exceed about 3%. Although actual consumption data were lacking, based on the reported capacities of various slag-grinding facilities, it may be estimated that the amount of GGBFS consumed to make cement (table 6) is likely only about 10% of that which ultimately makes its way into concrete. Likewise, the amount of ash consumed for cement is only a small fraction of the 9 Mt reported as consumed for cement (other than for clinker) and concrete manufacture in 1999 (American Coal Ash Association, 1999) and probably in 2000 (actual 2000 data are unavailable); the inference is that most of this consumption is directly by the concrete manufacturers.

White portland cement sales increased by about 5%, but some of the cement may represent material that was actually sold within a white or colored masonry product. Oil well cement sales rose by almost 80%, reflecting substantially increased drilling activities during the year.

Foreign Trade

Tables 17 through 22 list trade data from the U.S. Census Bureau. Exports of hydraulic cement and clinker (table 17) increased in 2000 but, excepting sales to Canada, were essentially insignificant, and overall, the exports continued to be of almost no consequence to the U.S. cement economy. Almost all of the exported material was cement.

The U.S. cement economy continued to be significantly import dependent, although total imports of hydraulic cement and clinker (tables 18-19) declined by 2.3% to 28.7 Mt (including Puerto Rico). This was the first annual decline since 1992 and reflected a combination of a slowing growth in demand and an increase in domestic production capacity. The import tonnage decrease was in stark contrast to increases of 22% in 1999, 37% in 1998, and 24% in 1997. The 2000 tonnage represents approximately 25% of the total world trade in cement and clinker, based on global estimates (International Cement Review, 2001). The average unit c.i.f. value of imports fell by 1.4% to $48.72 per ton; the decline was a combination of a 4.0% decrease in base (customs) value to $37.44 per ton and an 8.4% increase in combined shipping (mostly fuel-related) and insurance costs to $11.28 per ton.

The hydraulic cement component of imports (derived by subtracting clinker imports in table 22 from the table 18 data) totaled 24.9 Mt, virtually unchanged from that in 1999. Gray portland cement imports were 95.7% of this total and were up by only 0.7% (table 20). The c.i.f. value of gray portland cement imports fell by 2.3% to $46.65 per ton, within which the customs value fell 5.1% to $35.50 per ton, and the freight and insurance charges rose by 7.7% to $11.15 per ton. In 1999, the customs value had fallen by 4.7% and the shipping charges had risen by almost 10%. The total c.i.f. value of gray portland imports fell by 1.7% to $1.11 billion. Customs values in 2000 ranged from $21.13 per ton for cement from the Philippines to $51.81 per ton for Canadian cement. Shipping charges ranged from $3.43 per ton from Canada (railroad) to $24.07 per ton from the Philippines, but there was considerable overlap of shipping charge rates among various source countries and regions and the cement landing points (table 19); because of this overlap and the large number of variables within shipping charges, no firm shipping charge trends could be discerned. As noted in the "Values" subsection, the customs values listed are much lower than the U.S. mill net and/or terminal net values of portland cement sold to final customers (tables 12 and 14), making the United States an attractive market for surplus foreign production, and making it relatively easy for U.S. importers to absorb rising transportation costs, even for material sourced from vast distances.

Although Thailand replaced Canada as the largest single source of hydraulic cement and clinker imports combined, in 2000, Canada remained the largest source of gray portland cement (table 20). Gray portland imports from Canada fell by 3.5% in 2000 to 3.9 Mt. Thailand was second, with 3.6 Mt, up by 16.3%. China, which had been second in 1999, was third with 3.3 Mt, down by 19.3%.

White cement imports are listed in table 21, and rose by almost 12% during the year to 0.92 Mt. The unit value (c.i.f.) rose by 1.2% to $110.70 per ton. However, this average value and several of the specific country annual average values appear to be too low (see, for example, the entries for Norway and

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various Asian countries), reflecting very low unit values on certain individual monthly shipments (not shown). Likewise, the import tonnage appears to be too high. Unless reflecting dumped material, the most likely explanation for the low unit values is that the data include some gray portland cement, supposed to be reported under the Harmonized Tariff Schedule of the United States (HTS) code 2523.29.00 or that the importers mistakenly invoiced under the white cement HTS code (2523.21.00). Coding errors are difficult to verify, but past experience indicates that they do occur, though infrequently. Apart from the low overall value, evidence for misinclusion of gray cement is also found in some price differences between imported gray and white portland cement. For example, the 2000 imports of white cement from Indonesia calculate to a (suspiciously low) unit value (c.i.f.) of $54.61 per ton, which was only $10.43 per ton more than the unit value for imported Indonesian gray portland cement. This white cement premium is far smaller than normal, even considering expected general variability because of the imports perhaps comprising a mix of bulk and bag shipments. For U.S. cement imports overall, the premium for white cement was $64.05 per ton, and that for overall sales (table 14), $82.84 per ton. Finally, the white cement import tonnage appears to be out of line with the market for this material. Although the white cement market is very difficult to analyze—it being a fairly specialized product that is sensitive to a relatively small number of individual construction projects—the import tonnage increase exceeds the construction spending trends noted earlier. A final indication of problems with the white cement import data is that the total import volume exceeds the total white portland cement sales volume in table 16, which is inclusive of sales of domestically produced material. The excess appears to be much larger than could be reasonably accommodated by apportioning some imports to masonry cement sales (not included in table 16) or to yearend stockpiles. However, despite misgivings about some of the entries in table 21, the data therein for at least the major country sources calculate to realistic unit values and thus appear to be accurate. In 2000, Mexico was the largest source of white cement imports, followed by Canada, Denmark, and Spain.

Imports of clinker are listed in table 22. Total imports in 2000 fell by 17.7% to 3.8 Mt, and the unit c.i.f. value of the imports rose by 1.8% to $43.13 per ton. However, the data for both years are bolstered by the inclusion of a small quantity of very expensive aluminous cement clinker from France, the cement from which has very different applications than those for portland cement. If the French material is removed, the total remaining imports drop to 3.7 Mt (down by 17.1%), at a unit customs value of $29.41 per ton (down by 3.7%), and a unit c.i.f. value of $40.13 per ton (up by 2.2%).

Thailand continued to be the largest country source of the clinker imports, followed by Canada, which had been the largest source in 1999. The remaining major suppliers of clinker to the United States, in decreasing order, were Turkey, Colombia, China, and the Republic of Korea; neither Korea nor Turkey had supplied clinker to the United States in 1999. Excluding aluminous cement clinker, customs values for imported clinker ranged from $18.70 per ton for Chinese material to $51.42 per ton for imports from Canada. Thailand clinker had an average customs value of $19.82 per ton. Because of shipping costs, the price range was less extreme on a c.i.f. basis: Chinese clinker was $27.22 per ton, Canadian clinker was $53.67 per ton, and Thailand clinker was $35.10 per ton.

Imports of cement and clinker, by customs district of entry, are listed in table 19. New Orleans continued to be by far the busiest entry point for both cement and clinker; Detroit had been the largest clinker import venue in 1999. Much of the material coming into New Orleans was destined to be transferred onto barges for transport up the Mississippi River system. In terms of serving local markets, the largest cement-importing States were California, Florida, and Texas.

World Review

Individual country cement production data are listed in table 23. The data for some countries may include their exports of clinker. Although the data are supposed to include all forms of hydraulic cement, the data for the United States are for portland plus masonry cement only, and the data for some other countries also may not be all inclusive. Because data for many countries are estimated, the annual world totals (which have been rounded) must be viewed as estimates. As estimated, world hydraulic cement production increased by about 2.5% in 2000 to 1.64 Gt.

With production reported at 583.2 Mt, China was by far the largest cement producer in the world in 2000. Although precise data are lacking, India was in second place, and the United States was in third. The remainder of the top 15 cement-producing countries in 2000, in decreasing order, were Japan, the Republic of Korea, Brazil, Germany, Italy, Turkey, Russia, Thailand, Mexico, Spain, Indonesia, and Egypt. These top 15 countries accounted for about 75% of total world production and much of the growth in world production in the past decade. China alone, since 1995, has increased its output by 107 Mt/yr.

On a regional basis, Asia again accounted for about 59% of the world total production. This region, particularly Southeast Asia, was slowly recovering from the economic crisis that began in late 1997, and local cement production and consumption levels among the major cement economies increased in 2000; consumption, however, had yet to recover to precrisis levels. This meant that there were still substantial regional cement surpluses available for export at low base prices. Because of higher fuel (hence transportation) costs and generally weaker economies in the export target countries (particularly the United States), the cost advantage of importing cement from Southeast Asia was somewhat less than in 1999.

Europe retained its position as the second largest producing region; Western Europe accounted for 11.6% of world production, and Eastern Europe, 2.6%. North America, including Mexico, was the third largest producing region, with 8.1% of the total, and Latin America and the Caribbean had 5.4% of world output (this would be 7.3% if Mexico were included here). The Middle East, including Turkey, produced 6.3% of the world's cement, and Africa contributed 4.4%. Countries of the former Soviet Union produced only 2.9% of the world's cement in 2000 but had a great deal of surplus production capacity available.

There continued to be a large number of cement plant construction and/or modernization projects throughout the world, in many regions spurred by privatization programs and by the need for plants to conform to increasingly universal and stricter environmental standards. Much of the international investment was by a few major international cement companies,

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most based in Europe. For the most part, these were the same companies that controlled the U.S. cement industry. Geographic diversification of holdings was seen as an advantage, as it allowed a spreading of investment risk among many countries, a market share in regions of large economic growth potential, and access to a diversity of supply sources as needed. Many of the new plants under construction were very large, and many were geared, at least partly, to exports.

Outlook

Cement industry analysts at yearend were anticipating fairly stagnant or declining market conditions in 2001, followed by a small decline in demand for the next year or two, followed by a resumption in steady demand growth, albeit at modest rates of 1% to 3% per year, for the next few years thereafter. The pessimistic short-term outlook was based in part on the cold-weather-induced drastic falloff in cement consumption in November and December 1999 and a general slowdown in the U.S. economy, which looked not to be short-lived. Having been disappointed in 1999 and 2000 by highway construction levels that fell well short of predictions under the TEA-21 funding scenarios, the industry was adopting a wait-and-see attitude towards highway spending levels in 2001 though remaining optimistic that the TEA-21 funding would eventually generate large cement sales.

New plant and/or capacity expansion projects planned or underway in the United States total about 25 Mt/yr of new capacity coming on-line by 2005. Whether or not all of these projects come to fruition, significant capacity additions are certain. These additions likely will substantially reduce the need for imported cement and clinker, although plenty of this material was expected to remain available at attractive base prices. With the termination of antidumping remedies against Venezuela, it was expected that imports from that country could increase at the expense of material from other regional exporters.

Although there was little expectation that the Kyoto Protocol would be ratified, the industry expected that pressures to reduce emissions of CO_2 and that other pollutants would increase, and several companies were taking steps to adopt proactive policies on their plants' environmental performances.

References Cited

American Coal Ash Association, 1999, 1999 coal combustion product (CCP) production and use (short tons): Alexandria, VA, American Coal Ash Association fact sheet, 2 p.

Arthur, Steve, 2000, Holnam—Building for the future: World Cement, v. 31, no. 12, p. 50-54.

Ash Grove Cement Co., 2001, Ash Grove sets the pace: International Cement Review, May, p. 51-57.

Barzoloski, Alfred, 2000, Colossal progress: World Cement, v. 31, no. 5, p. 38-39.

Cement Americas, 2001, Holnam gets the go ahead for new Missouri plant: Cement Americas, March-April, p. 12-14.

Cohrs, C.O., 2001, The next generation: International Cement Review, June, p. 55-60.

Intergovernmental Panel on Climate Change, 2000, CO_2 emissions from industry, ch. 3 *of* Good practice guidance and uncertainty management in national greenhouse gas inventories: Hayama, Japan, Institute for Global Environmental Strategies, p. 3.1-3.29.

International Cement Review, 2000a, Italcimenti to expand: International Cement Review, August, p. 12.

———2000b, New capacity brings down Texas prices: International Cement Review, December, p. 8.

———2001, Back to the future: International Cement Review, February, p. 15-19.

Maranzana, Michele, 2000, Technological efficiency: World Cement, v. 31, no. 5, p. 40-44.

Martin, Nathan, Worrel, Ernst, and Price, Lynn, 1999, Energy efficiency and carbon dioxide emissions reduction opportunities in the U.S. cement industry: Berkeley, CA, Ernest Orlando Lawrence Berkeley National Laboratory report no. LBNL-44182, 40 p.

Mining Engineering, 2001, Greencastle expands, uses new production process: Mining Engineering, v. 53, no. 1, January, p. 31-33.

Oil & Gas Journal, 2001, Baker Hughes rig count: Oil & Gas Journal, v. 99.2, January 8, p. 77.

Perkins, David, 2000, Increased production and lower emissions: World Cement, v. 31, no. 12, December, p. 57-59.

Portland Cement Association, 2000a, Cement industry update: Monitor, v. 10, no. 1, January, p. 2.

———2000b, Cement industry update: Monitor, v. 10, no. 2, February, p. 2.

———2001, Construction put in place: Monitor, v. 11, no. 4, p. 16.

Southern Tier Cement Committee, 2000a, Commerce Department determines high dumping margin on cement imports from Mexico for eighth consecutive year: Washington, DC, King & Spaulding press release, March 7, 2 p.

———2000b, Commerce Department determines that heavy dumping of cement imports from Mexico and Venezuela will resume if existing antidumping relief is revoked: Washington, DC, King & Spaulding press release, June 29, 2 p.

———2000c, U.S. International Trade Commission votes in sunset review on gray portland cement to continue the U.S. antidumping orders on imports from Mexico and Japan: Washington, DC, King & Spaulding press release, October 5, 3 p.

U.S. Environmental Protection Agency, 2001, Executive summary, *in* Inventory of U.S. greenhouse gas emissions and sinks—1990-1999: Washington, DC, U.S. Environmental Protection Agency, p. ES 1—ES-26.

Wahlquist, Craig, 2000, NOx reduction and destruction: World Cement, v. 31, no. 10, p. 84-89.

Whitehorn, Anna, 2001, Adding fuel to the fire: International Cement Review, March, p. 69-70.

World Cement, 2000, Blue Circle expansion: World Cement, v. 31, no. 2, p. 5.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Cement. Ch. in Mineral Commodity Summaries, annual.
Cement. Ch. in Minerals Yearbook, annual.
Cement. Mineral Industry Surveys, monthly.

Other

American Portland Cement Alliance, Washington, DC.
Cement. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Cement Americas, bimonthly.
North American Cement Directory: Intertec Publishing, Chicago, annual.
Concrete Products, monthly.
Engineering News-Record, weekly.
International Cement Review, monthly.
Portland Cement Association, Skokie, IL, The Monitor, monthly.
U.S. and Canadian Portland Cement Industry: Plant Information Summary, annual.
Rock Products, monthly.
World Cement, monthly.
World Cement Directory. The European Cement Association, Brussels, Belgium, 1996.
Zement-Kalk-Gyps International, monthly.

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TABLE 1
SALIENT CEMENT STATISTICS 1/

(Thousand metric tons unless otherwise specified)

	1996	1997	1998	1999	2000
United States: 2/					
Production 3/	79,266	82,582	83,931	85,952	87,846
Production of clinker	70,361	72,686	74,523	76,003	78,138
Shipments from mills and terminals 4/	83,963	90,359	96,857	103,271	105,557
Value 5/ thousands	$5,952,203	$6,637,464	$7,404,394	$8,083,247	$8,292,625
Average value per ton 6/	$70.89	$73.46	$76.45	$78.27	$78.56
Stocks at mills and terminals, yearend 3/	5,488	5,784	5,393	6,367	7,566
Exports 7/	803	791	743	694	738
Imports for consumption:					
Cement 8/	11,565	14,523	19,878	24,578	24,561
Clinker	2,402	2,867	3,905	4,164	3,673
Total	13,967	17,390	23,783	28,742	28,234
Consumption, apparent 9/	90,355	96,018	103,457	108,862	110,470
World production e/ 10/	1,493,000 r/	1,547,000	1,547,000 r/	1,603,000 r/	1,643,000

e/ Estimated. r/ Revised.

1/ Portland and masonry cements only, unless otherwise indicated.

2/ Excludes Puerto Rico.

3/ Includes cement produced from imported clinker.

4/ Shipments are to final customers. Includes imported cement. Data are based on annual survey of individual plants and terminals and may differ from tables 9 and 10, which are based on consolidated monthly shipments data from companies.

5/ Value at mill or import terminal of portland (all types) and masonry cement shipments to final domestic customers. Although presented unrounded, the data contain estimates for survey nonrespondents.

6/ Total value at mill or import terminal of cement shipments to final customers divided by total tonnage of same. Although presented unrounded, the data contain estimates for survey nonrespondents.

7/ Hydraulic cement (all types) plus clinker.

8/ Hydraulic cement, all types.

9/ Production (including that from imported clinker) of portland and masonry cement plus imports of hydraulic cement minus exports of cement minus change in stocks.

10/ Total hydraulic cement. May incorporate clinker exports for some countries.

TABLE 2
COUNTY BASIS OF SUBDIVISION OF STATES IN CEMENT TABLES

State subdivision	Defining counties
California, northern	Alpine, Fresno, Kings, Madera, Mariposa, Monterey, Tulare, Tuolumne, and all counties farther north.
California, southern	Inyo, Kern, Mono, San Luis Obispo, and all counties farther south.
Chicago, metropolitan	Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties in Illinois.
Illinois	All counties other than those in metropolitan Chicago.
New York, eastern	Delaware, Franklin, Hamilton, Herkimer, Otsego, and all counties farther east and south, excepting those within Metropolitan New York.
New York, western	Broome, Chenango, Lewis, Madison, Oneida, St. Lawrence, and all counties farther west.
New York, metropolitan	New York City (Bronx, Kings, New York, Queens, and Richmond), Nassau, Rockland, Suffolk, and Westchester.
Pennsylvania, eastern	Adams, Cumberland, Juniata, Lycoming, Mifflin, Perry, Tioga, Union, and all counties farther east.
Pennsylvania, western	Centre, Clinton, Franklin, Huntingdon, Potter, and all counties farther west.
Texas, northern	Angelina, Bell, Concho, Crane, Culberson, El Paso, Falls, Houston, Hudspeth, Irion, Lampasas, Leon, Limestone, McCulloch, Reeves, Reagan, Sabine, San Augustine, San Saba, Tom Green, Trinity, Upton, Ward, and all counties farther north.
Texas, southern	Brazos, Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, Williamson, and all counties farther south.

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TABLE 3
PORTLAND CEMENT PRODUCTION, CAPACITY, AND STOCKS IN THE UNITED STATES, BY DISTRICT

(Thousand metric tons unless otherwise specified)

	1999					2000				
			Capacity 1/		Stocks			Capacity 1/		Stocks
District	Plants active 2/	Production 3/	Finish grinding	Percentage utilized	at yearend 4/	Plants active 2/	Production 3/	Finish grinding	Percentage utilized	at yearend 4/
Maine and New York	4	3,285	3,756	87.5	237	5	3,140	3,846	81.6	313
Pennsylvania, eastern 5/	7	4,710	5,205	90.5	263	7	4,685	5,374	87.2	251
Pennsylvania, western	4	1,980	2,222	89.1	107	4	1,950	2,540	79.8	183
Illinois	4	2,939	3,507	83.8	193	4	2,861	3,787	75.5	290
Indiana	4	2,511	3,052	82.2	190	4	2,634	3,456	76.2	303
Michigan	5	5,813	7,663	75.8	418	5	5,785	7,881	73.4	411
Ohio	2	1,132	1,515	74.7	65	2	1,034	1,497	69.1	73
Iowa, Nebraska, South Dakota	5	4,092	5,452	75.1	342	5	4,255	5,479	77.7	424
Kansas	4	1,974	2,085	94.7	133	4	1,983	2,085	95.1	206
Missouri	5	4,910	5,330	92.1	589	5	4,884	5,186	94.2	634
Florida	7	3,497	6,355	55.0	411	7	3,753	6,817	55.1	411
Georgia, Virginia, West Virginia	4	2,712	3,396	79.8	190	4	3,042	4,656	65.3	209
Maryland	3	1,728	1,837	94.1	97	3	1,756	1,992	88.2	107
South Carolina	3	2,610	3,335	78.3	80	3	2,912	3,361	86.6	172
Alabama	5	4,301	5,005	85.9	267	5	4,337	5,020	86.4	331
Kentucky, Mississippi, Tennessee	4	2,361	2,631	89.8	172	4	2,209	3,545	62.3	191
Arkansas and Oklahoma	4	2,650	3,162	83.8	183	4	2,663	3,162	84.2	281
Texas, northern 5/	6	4,203	4,878	86.2	242	6	4,752	6,012	79.0	370
Texas, southern	5	4,479	4,840	92.6	212	5	4,515	4,842	93.2	247
Arizona and New Mexico	3	2,238	2,336	95.8	83	3	2,175	2,336	93.1	111
Colorado and Wyoming	4	2,128	2,428	87.7	147	4	2,253	2,453	91.9	133
Idaho, Montana, Nevada, Utah	7	2,781	3,306	84.1	222	7	2,818	3,415	82.5	260
Alaska and Hawaii	1	254	499	50.9	49	1	286	288	99.5	27
California, northern	3	2,770	2,862	96.8	159	3	2,811	2,880	97.6	124
California, southern 5/	8	7,519	8,315	90.4	395	8	8,066	9,015	89.5	334
Oregon and Washington	4	1,999	2,598	77.0	238	4	1,953	2,498	78.2	170
Total or average 6/	115	81,577	97,568	83.6	5,902 7/	116	83,514	103,426	80.7	6,564 7/
Puerto Rico	2	1,825	2,065	88.4	34	2	1,664	2,065	80.6	33

1/ Reported annual grinding capacity based on fineness necessary to grind individual plants' normal product mixes, making allowance for downtime required for routine maintenance.
2/ Includes one plant that reported portland cement (clinker) grinding capacity but no production of portland cement.
3/ Includes cement produced from imported clinker.
4/ Includes imported cement. Includes mills and terminals.
5/ Includes data for white cement.
6/ Data may not add to totals shown because of independent rounding.
7/ Total stocks include inventory, not included on a district basis, held by independent importers.

TABLE 4
MASONRY CEMENT PRODUCTION AND STOCKS IN THE UNITED STATES, BY DISTRICT

(Thousand metric tons unless otherwise specified)

	1999			2000		
District	Plants active	Production 1/	Stocks at yearend 2/	Plants active	Production 1/	Stocks at yearend 2/
Maine and New York	4	122	18	4	130	11
Pennsylvania, eastern	6	219	35	6	225	41
Pennsylvania, western	4	111	13	4	99	16
Indiana	4	W	51	4	444	62
Michigan	5	283	31	5	296	37
Ohio	2	85	17	2	92	27
Iowa, Nebraska, South Dakota	3	W	6	3	W	10
Kansas	2	W	W	2	W	W
Missouri	1	W	W	1	W	W
Florida	4	494	40	5	543	35
Georgia, Virginia, West Virginia	5	370	46	5	331	36

See footnotes at end of table.

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TABLE 4--Continued
MASONRY CEMENT PRODUCTION AND STOCKS IN THE UNITED STATES, BY DISTRICT

(Thousand metric tons unless otherwise specified)

District	1999			2000		
	Plants active	Production 1/	Stocks at yearend 2/	Plants active	Production 1/	Stocks at yearend 2/
Maryland	3	110	19	3	78	19
South Carolina	3	421	32	3	411	25
Alabama	4	429	56	4	401	57
Kentucky, Mississippi, Tennessee	3	W	W	3	83	6
Arkansas and Oklahoma	4	138	13	4	142	25
Texas, northern	4	153	10	4	156	9
Texas, southern	3	108	7	3	112	7
Arizona and New Mexico	3	W	6	3	W	W
Colorado and Wyoming	2	W	W	2	W	W
Idaho, Montana, Nevada, Utah	--	--	(3/)	1	W	W
Alaska and Hawaii	1	3	(3/)	1	3	--
California	6	417 4/	14 4/	6	484	18
Total 5/	76	4,375 6/	466 7/	78	4,332 6/	492

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Includes cement produced from imported clinker.
2/ Includes imported cement.
3/ Less than 1/2 unit.
4/ Includes data for southern California only. Northern California data are withheld.
5/ Data may not add to totals shown because of independent rounding. Includes withheld districts.
6/ Production directly from clinker accounted for almost 94% of the total in 1999 and 95% in 2000. Production from portland cement accounted for the remainder.
7/ Total stocks include inventory, not shown on a district basis, held by independent importers.

TABLE 5
CLINKER CAPACITY AND PRODUCTION IN THE UNITED STATES IN 2000, BY DISTRICT

(Thousand metric tons unless otherwise specified)

District	Active plants 1/				Number of kilns	Daily capacity	Average days of routine maintenance	Apparent annual capacity 2/	Production	Percentage of capacity utilized	Yearend stocks 3/
	Process used										
	Wet	Dry	Both	Total							
Maine and New York	3	1	--	4	5	10.4	39.2	3,411	3,090	90.6	133
Pennsylvania, eastern	2	5	--	7	14	15.2	24.4	5,101	4,590	90.0	189
Pennsylvania, western	3	1	--	4	8	6.1	23.0	2,110	1,964	93.1	235
Illinois	--	4	--	4	8	8.4	19.6	2,829	2,484	87.8	276
Indiana	1	3 4/	--	4	8	10.2	26.0	3,430	2,544	74.2	186
Michigan	1	2	--	3	8	13.5	23.0	4,604	4,347	94.4	346
Ohio	1	1	--	2	3	3.5	24.7	1,196	1,038	86.7	66
Iowa, Nebraska, South Dakota	--	4	1	5	9	13.6	25.7	4,632	3,983	86.0	282
Kansas	2	2	--	4	11	5.6	19.5	1,958	1,789	91.4	207
Missouri	2	3	--	5	7	14.0	24.9	4,662	4,558	97.8	315
Florida	1	4	--	5	7	12.6	23.0	4,315	3,472	80.5	226
Georgia, Virginia, West Virginia	1	3	--	4	7	10.6	29.3	3,608	2,937	81.4	209
Maryland	1	2	--	3	7	5.5	29.0	1,871	1,654	88.4	52
South Carolina	2	1	--	3	7	8.7	16.9	3,015	2,507	83.2	162
Alabama	--	5	--	5	6	14.1	17.8	4,808	4,161	86.5	264
Kentucky, Mississippi, Tennessee	2	2	--	4	5	8.8	17.6	3,038	2,132	70.2	336
Arkansas and Oklahoma	2	2	--	4	10	7.7	19.0	2,665	2,526	94.8	89
Texas, northern	3	3	--	6	15	16.4	20.4	5,752	4,607	80.1	165
Texas, southern	--	4	1	5	6	13.4	22.0	4,606	4,266	92.6	230
Arizona and New Mexico	--	3	--	3	9	6.5	17.4	2,240	2,184	97.5	151
Colorado and Wyoming	1	3	--	4	7	7.0	12.0	2,463	2,182	88.6	180
Idaho, Montana, Nevada, Utah	3	4	--	7	9	8.7	20.7	3,014	2,786	92.4	192
Alaska and Hawaii	--	--	--	--	--	--	--	--	--	--	35

See footnotes at end of table.

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TABLE 5--Continued
CLINKER CAPACITY AND PRODUCTION IN THE UNITED STATES IN 2000, BY DISTRICT

(Thousand metric tons unless otherwise specified)

District	Active plants 1/ Process used Wet	Dry	Both	Total	Number of kilns	Daily capacity	Average days of routine maintenance	Apparent annual capacity 2/	Production	Percentage of capacity utilized	Yearend stocks 3/
California, northern	--	3	--	3	3	8.7	33.0	2,872	2,721	94.7	145
California, southern	--	8	--	8	17	26.2	26.1	8,979	7,897	88.0	560
Oregon and Washington	1	2	--	3	3	6.3	35.3	2,085	1,721	82.5	88
Total or average 5/	32	75	2	109	199	261.5	23.0	89,264	78,138	87.5	5,321
Puerto Rico	--	2	--	2	2	5.9	34.0	1,964	1,518	77.3	252

-- Zero.

1/ Includes white cement plants.

2/ Calculated on a per-kiln basis using 366 days (leap year) minus reported days for routine maintenance and multiplied by the reported unrounded daily capacity.

3/ Includes imported clinker.

4/ Includes one semidry plant.

5/ Data may not add to totals shown because of independent rounding.

TABLE 6
RAW MATERIALS USED IN PRODUCING CLINKER AND CEMENT IN THE UNITED STATES 1/ 2/

(Thousand metric tons)

Raw materials	1999 Clinker	1999 Cement 3/	2000 Clinker	2000 Cement 3/
Calcareous:				
Limestone (includes aragonite, marble, chalk, coral)	91,021	1,138	93,947	1,263
Cement rock (includes marl)	23,981 r/	149 r/	21,820	133
Cement kiln dust 4/	305	112	351	155
Lime 5/	10	46	19	49
Other	--	--	21	225
Aluminous:				
Clay	4,770	23	4,205	8
Shale	3,679	--	3,743	3
Other (includes staurolite, bauxite, aluminum dross, alumina, and other)	387	--	400	--
Ferrous, iron ore, pyrites, millscale, other	1,259	--	1,310	--
Siliceous:				
Sand and calcium silicate	2,959	4	3,142	--
Sandstone, quartzite, other	745	--	925	--
Fly ash	1,521	85	1,679	88
Other ash, including bottom ash	760	--	930	--
Granulated blast furnace slag	--	349	--	303
Other blast furnace slag	97	--	43	--
Steel slag	591	--	805	--
Other slags	45	--	12	10
Natural rock pozzolans 6/	--	16	--	40
Other pozzolans 7/	38	4	38	8
Other:				
Gypsum and anhydrite	--	4,643	--	4,655
Clinker, imported 8/	--	4,607	--	4,573
Other, n.e.c.	--	51	--	46
Total 9/	132,169 r/	11,227 r/	133,391	11,558

r/ Revised. -- Zero.

1/ Includes Puerto Rico.

2/ Nonfuel materials only.

3/ Includes portland, blended, and masonry cements.

4/ Data are probably underreported.

5/ Data are probably underreported on the basis of reported volumes of masonry cements.

6/ Includes pozzolana and burned clays and shales.

7/ Includes diatomite, other microcrystalline silica, silica fume, and other pozzolans, whether or not used as such.

8/ Outside purchases by domestic plants; excludes purchases of domestic clinker.

9/ Data may not add to totals shown because of independent rounding.

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TABLE 7
CLINKER PRODUCED AND FUEL CONSUMED BY THE CEMENT INDUSTRY IN THE UNITED STATES, BY PROCESS 1/ 2/

	Clinker produced			Fuel consumed					Waste fuel		
Kiln process	Plants active	Quantity (thousand metric tons)	Percentage of total	Coal 3/ (thousand metric tons)	Coke (thousand metric tons)	Petroleum coke (thousand metric tons)	Oil (thousand liters)	Natural gas (thousand cubic meters)	Tires (thousand metric tons)	Solid (thousand metric tons)	Liquid (thousand liters)
1999:											
Wet	34	18,912	24.5	2,394	123	410	25,313	137,105	90	241	819,209
Dry	75	57,014	73.7	6,610	220	1,183	108,509 r/	433,682	586	575	86,319
Both	2	1,411	1.8	202	--	29	--	82,349	9	--	--
Total 4/	111	77,337	100.0	9,206	343	1,622	133,822 r/	653,136	685	816	905,527
2000:											
Wet	32	17,911	22.5	2,409	96	390	32,513	51,482	106	149	801,288
Dry	77	60,172	75.5	7,479	346	920	91,153	206,729	259	867	127,799
Both	2	1,574	2.0	208	--	41	--	80,049	8	--	--
Total 4/	111	79,656	100.0	10,095	442	1,351	123,666	338,261	374	1,016	929,087

r/ Revised. -- Zero.
1/ Includes portland and masonry cement. Excludes grinding plants.
2/ Includes Puerto Rico.
3/ All reported to be bituminous.
4/ Data may not add to totals shown because of independent rounding.

TABLE 8
ELECTRIC ENERGY USED AT CEMENT PLANTS IN THE UNITED STATES, BY PROCESS 1/

	Electric energy used							
	Generated at plant		Purchased		Total			
Plant process	Number of plants	Quantity (million kilowatt-hours)	Number of plants	Quantity (million kilowatt-hours)	Quantity (million kilowatt-hours)	Percentage	Finished cement 2/ produced (thousand metric tons)	Average consumption (kilowatt-hours per ton of cement produced)
1999:								
Integrated plants:								
Wet	--	--	34	2,859	2,859	23.5	21,789	131
Dry	4	486	75	8,601	9,087	74.6	61,804	147
Both	--	--	2	238	238	2.0	1,652	144
Total or average 3/	4	486	111	11,699	12,185	100.0	85,245	143
Grinding plants 4/	--	--	5	154	154	--	2,368	65
Exclusions 5/	--	--	3	--	--	--	165	--
2000:								
Integrated plants:								
Wet	--	--	32	2,685	2,685	21.4	20,544	131
Dry	4	497	77	9,095	9,592	76.6	64,930	148
Both	--	--	2	249	249	2.0	1,593	157
Total or average 3/	4	497	111	12,029	12,526	100.0	87,067	144
Grinding plants 4/	--	--	6	164	164	--	2,294	71
Exclusions 5/	--	--	2	--	--	--	149	--

-- Zero.
1/ Includes Puerto Rico.
2/ Includes portland and masonry cements.
3/ Data may not add to totals shown because of independent rounding.
4/ Excludes plants that reported production only of masonry cement.
5/ Tonnage of cement produced by plants that reported production of masonry cement only. One plant reported portland cement grinding capacity and so is included in table 3.

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TABLE 9
CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN 1/ 2/

(Thousand metric tons)

Destination and origin	Portland cement		Masonry cement	
	1999	2000	1999	2000
Destination:				
Alabama	1,514	1,565	155	145
Alaska 3/	120	127	--	--
Arizona	3,199	3,236	112	109
Arkansas	994	952	59	54
California, northern	4,309	4,706	60	63
California, southern	7,432	7,959	367	368
Colorado	2,476	2,597	30	43
Connecticut 3/	785	838	15	15
Delaware 3/	230	165	11	11
District of Columbia 3/	133	178	(4/)	2
Florida	7,094	7,694	553	591
Georgia	3,386	3,434	301	302
Hawaii	251	288	4	4
Idaho	536	558	1	1
Illinois, excluding Chicago	1,612	1,524	28	24
Illinois, Chicago, metropolitan 3/	2,297	2,312	57	62
Indiana	2,311	2,208	103	96
Iowa	1,766	1,710	10	8
Kansas	1,545	1,490	16	15
Kentucky	1,425	1,322	106	98
Louisiana 3/	1,874	1,790	59	55
Maine	219	221	6	5
Maryland	1,237	1,333	83	88
Massachusetts 3/	1,585	1,580	24	23
Michigan	3,486	3,489	160	160
Minnesota 3/	1,987	2,010	32	37
Mississippi	1,016	936	63	56
Missouri	2,590	2,562	42	42
Montana	334	318	1	1
Nebraska	1,114	1,079	10	9
Nevada	1,844	1,963	30	31
New Hampshire 3/	280	268	8	6
New Jersey 3/	1,836	1,915	75	73
New Mexico	777	831	5	6
New York, eastern	602	637	25	30
New York, western 3/	915	871	37	36
New York, metropolitan 3/	1,552	1,677	55	57
North Carolina 3/	2,733	2,764	336	319
North Dakota 3/	336	308	4	3
Ohio	4,171	3,907	199	190
Oklahoma	1,376	1,421	48	45
Oregon	1,053	1,003	1	1
Pennsylvania, eastern	2,134	2,212	60	66
Pennsylvania, western	1,261	1,162	73	66
Rhode Island 3/	178	154	4	3
South Carolina	1,357	1,318	141	139
South Dakota	401	432	3	3
Tennessee	2,264	2,097	236	223
Texas, northern	5,463	5,540	194	198
Texas, southern	6,064	6,005	121	126
Utah	1,509	1,432	(4/)	1
Vermont 3/	138	145	3	3
Virginia	2,074	2,216	154	156
Washington	2,020	2,016	3	3
West Virginia	406	417	30	26
Wisconsin 3/	2,363	2,185	36	33
Wyoming	228	248	1	1
U.S. total 5/	104,195	105,322	4,353	4,333
Foreign countries 6/	315	393	(4/)	--
Puerto Rico	1,810	1,663	(4/)	--
Grand total 5/	106,320	107,378	4,353	4,333

See footnotes at end of table.

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TABLE 9--Continued
CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN 1/ 2/

(Thousand metric tons)

Destination and origin	Portland cement		Masonry cement	
	1999	2000	1999	2000
Origin:				
United States	82,032	83,787	4,296	4,281
Puerto Rico	1,810	1,663	--	--
Foreign countries 7/	22,478	21,927	56	52
Total shipments 5/	106,320	107,378	4,353	4,333

-- Zero.
1/ Includes cement produced from imported clinker and imported cement shipped by domestic producers and importers.
2/ Data are developed from consolidated monthly surveys of shipments by companies and may differ from data in tables 1, 11-13, 15, and 16, which are from annual surveys of individual plants and importers.
3/ Has no cement plants.
4/ Less than 1/2 unit.
5/ Data may not add to totals shown because of independent rounding.
6/ Includes shipments to U.S. possessions and territories.
7/ Imported cement distributed in the United States by domestic producers and other importers.

TABLE 10
CEMENT SHIPMENTS, BY DESTINATION (REGION AND CENSUS DISTRICT) 1/ 2/

Region and census district	Portland cement				Masonry cement			
	Quantity (thousand metric tons)		Percentage of U.S. total		Quantity (thousand metric tons)		Percentage of U.S. total	
	1999	2000	1999	2000	1999	2000	1999	2000
Northeast:								
New England 3/	3,185	3,206	3	3	60	55	1	1
Middle Atlantic 4/	8,300	8,474	8	8	325	328	7	8
Total 5/	11,485	11,680	11	11	385	383	9	9
South:								
South Atlantic 6/	18,650	19,519	18	19	1,609	1,634	37	38
East South Central 7/	6,219	5,920	6	6	560	522	13	12
West South Central 8/	15,771	15,708	15	15	481	478	11	11
Total 5/	40,640	41,147	39	39	2,650	2,634	61	61
Midwest:								
East North Central 9/	16,240	15,625	16	15	583	565	13	13
West North Central 10/	9,739	9,591	9	9	117	117	3	3
Total 5/	25,979	25,216	25	24	700	682	16	16
West:								
Mountain 11/	10,903	11,183	10	11	180	193	4	4
Pacific 12/	15,185	16,099	15	15	435	439	10	10
Total 5/	26,088	27,282	25	26	,615	,632	14	15
U.S. total 5/	104,195	105,322	100	100	4,353	4,333	100	100

1/ Includes imported cement shipped by importers and cement ground from imported clinker. Excludes Puerto Rico.
2/ Data are based on table 9.
3/ New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
4/ Middle Atlantic includes New Jersey, New York, and Pennsylvania.
5/ Data may not add to totals shown because of independent rounding.
6/ South Atlantic includes Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.
7/ East South Central includes Alabama, Kentucky, Mississippi, and Tennessee.
8/ West South Central includes Arkansas, Louisiana, Oklahoma, and Texas.
9/ East North Central includes Illinois, Indiana, Michigan, Ohio, and Wisconsin.
10/ West North Central includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.
11/ Mountain includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.
12/ Pacific includes Alaska, California, Hawaii, Oregon, and Washington.

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TABLE 11
SHIPMENTS OF PORTLAND CEMENT FROM MILLS IN THE UNITED STATES, IN BULK AND IN CONTAINERS, BY TYPE OF CARRIER 1/

(Thousand metric tons)

	Shipments from plant to terminal		Shipments to final domestic consumer				
			From plant to consumer		From terminal to consumer		Total
	In bulk	In containers 2/	In bulk	In containers 2/	In bulk	In containers 2/	shipments to consumer
1999:							
Railroad	11,137	47	2,851	562	800	45	4,259
Truck	4,132	122	55,101	2,071	38,582	565	96,319
Barge and boat	9,993	--	149	--	(3/)	--	149
Other	--	--	--	--	20	--	20
Total 4/	25,262	169	58,101	2,634	39,402	611	100,746 5/
2000:							
Railroad	11,865	42	1,529	2	479	1	2,010
Truck	4,211	308	56,482	2,464	41,066	737	100,749
Barge and boat	8,082	--	183	--	6	--	188
Other	--	--	--	--	--	--	--
Total 4/	24,158	350	58,193	2,466	41,550	737	102,947 5/

-- Zero.

1/ Includes Puerto Rico. Includes imported cement and cement made from imported clinker.

2/ Includes bags and jumbo bags.

3/ Less than 1/2 unit.

4/ Data may not add to totals shown because of independent rounding.

5/ Shipments calculated on the basis of an annual survey of plants and importers; may differ from tables 9 and 10, which are based on consolidated company monthly data.

TABLE 12
PORTLAND CEMENT SHIPPED BY PRODUCERS AND IMPORTERS IN THE UNITED STATES, BY DISTRICT 1/ 2/

	1999			2000		
	Quantity	Value 3/		Quantity	Value 3/	
District 4/ 5/	(thousand metric tons) 6/	Total (thousands)	Average per metric ton	(thousand metric tons) 6/	Total (thousands)	Average per metric ton
Maine and New York	3,653	$267,464	$73.21	3,422	$267,991	$78.32
Pennsylvania, eastern	4,709	323,732	68.74	4,832	335,078	69.34
Pennsylvania, western	1,788	141,769	79.30	1,412	112,338	79.55
Illinois	2,862	208,919	73.00	2,868	218,777	76.27
Indiana	2,986	211,572	70.86	2,932	199,744	68.13
Michigan	5,922	447,474	75.56	5,766	448,703	77.81
Ohio	1,275	102,203	80.18	1,174	94,503	80.53
Iowa, Nebraska, South Dakota	4,764	369,329	77.52	4,779	376,357	78.76
Kansas	1,754	131,952	75.23	1,693	132,298	78.13
Missouri	6,377	459,575	72.07	5,988	455,724	76.11
Florida	6,790	505,609	74.47	7,325	549,569	75.02
Georgia, Virginia, West Virginia	3,042	236,815	77.85	3,055	238,729	78.13
Maryland	1,645	118,248	71.87	1,675	118,776	70.93
South Carolina	2,804	219,892	78.41	2,661	192,178	72.21
Alabama	4,303	348,740	81.05	4,539	357,813	78.83
Kentucky, Mississippi, Tennessee	2,676	210,448	78.63	2,544	197,836	77.77
Arkansas and Oklahoma	2,924	216,170	73.92	2,659	209,528	78.80
Texas, northern	4,904	384,512	78.40	5,282	410,079	77.64
Texas, southern	5,718	421,881	73.78	5,608	392,860	70.05
Arizona and New Mexico	3,668	339,823	92.66	3,610	350,231	97.03
Colorado and Wyoming	2,385	194,784	81.66	2,581	232,221	89.97
Idaho, Montana, Nevada, Utah	2,965	253,987	85.66	2,965	245,179	82.70
Alaska and Hawaii	335	32,558	106.29 r/	381	39,880	104.67
California, northern	3,052	261,235	85.60	3,749	303,316	80.90
California, southern	8,485	654,767	77.16	9,004	669,445	74.35
Oregon and Washington	3,040	240,578	79.13	2,225	177,615	79.83
Independent importers, n.e.c. 7/	4,105	331,593	80.78	6,552	506,655	77.33
Total or average 8/	98,933	7,635,631	77.21 r/	101,282	7,833,425	77.34
Puerto Rico	1,814	W	W	1,665	W	W

See footnotes at end of table.

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TABLE 12--Continued
PORTLAND CEMENT SHIPPED BY PRODUCERS AND IMPORTERS IN THE UNITED STATES, BY DISTRICT 1/ 2/

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Includes imported cement and cement produced from imported clinker.
2/ Includes white cement.
3/ Values represent ex-plant (f.o.b. plant) data collected for total shipments to final customers, not for shipments by specific type of portland cement. Although presented unrounded, the data incorporate estimates for some plants. Accordingly, the data should be viewed as cement value indicators, accurate to no better than the nearest $0.50 or even $1.00.
4/ The district location is that of the reporting facility. Shipments may include material sold into other districts.
5/ Includes shipments by independent importers where district assignation is possible.
6/ Shipments calculated on the basis of an annual survey of plants and importers; may differ from tables 9 and 10, which are based on consolidated company monthly data.
7/ Shipments by importers for which district assignations were not possible.
8/ Data may not add to totals shown because of independent rounding.

TABLE 13
MASONRY CEMENT SHIPPED BY PRODUCERS AND IMPORTERS IN THE UNITED STATES, BY DISTRICT 1/ 2/ 3/

	1999			2000		
	Quantity	Value 4/		Quantity	Value 4/	
District 5/ 6/	(thousand metric tons) 7/	Total (thousands)	Average per metric ton	(thousand metric tons) 7/	Total (thousands)	Average per metric ton
Maine and New York	130	$12,516	$96.65	104	$10,258	$98.95
Pennsylvania, eastern	233	25,429	108.98	243	27,455	112.99
Pennsylvania, western	109	11,635	106.94	98	10,470	107.23
Illinois, Indiana, Ohio	525	52,667	100.34	491	52,949	107.76
Michigan	293	29,049	99.05	293	28,686	97.75
Iowa, Nebraska, South Dakota	44	4,071	92.38	40	3,750	93.69
Kansas and Missouri	145	9,918	68.42	141	11,957	85.07
Florida	477	49,187	103.09	519	61,952	119.43
Georgia, Virginia, West Virginia	311	40,948	131.51	306	40,029	130.72
Maryland	85	7,770	90.91	73	6,641	91.54
South Carolina	387	45,401	117.46	385	42,709	110.80
Alabama	458	50,836	111.01	442	50,166	113.61
Kentucky, Mississippi, Tennessee	94	9,212	97.89	87	8,516	97.96
Arkansas and Oklahoma	140	12,670	90.29	131	11,473	87.88
Texas	242	27,335	112.84	250	26,786	107.31
Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Utah, Wyoming	152	15,071	99.21	146	15,075	103.44
Alaska and Hawaii	3	331	96.98	4	772	214.95
California, Oregon, Washington	469	38,757	82.62	484	43,171	89.19
Independent importers, n.e.c. 8/	39	4,812	122.09	40	6,385	158.79
Total or average 9/	4,338	447,616	103.19	4,275	459,200	107.42

1/ Shipments are to final domestic customers and include shipments of imported cement and cement made from imported clinker.
2/ Includes white cement.
3/ Excludes Puerto Rico (did not record sales of masonry cement).
4/ Values are mill net and represent ex-plant (f.o.b. plant or import terminal) data collected for total shipments to final customers, not for shipments by cement type. Although presented unrounded, the data incorporate estimates for some plants. Accordingly, the data should be viewed as cement value indicators, accurate to no better than the nearest $0.50 or even $1.00 per ton.
5/ The district location is that of the reporting facility. Shipments may include material sold into other districts.
6/ Includes shipments by independent importers where district assignation is possible.
7/ Shipments calculated on the basis of an annual survey of plants and importers; may differ from tables 9 and 10, which are based on consolidated company monthly data.
8/ Shipments by importers for which district assignations were not possible.
9/ Total includes imports shipped by independent importers.

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TABLE 14
AVERAGE MILL NET VALUE OF CEMENT IN THE UNITED STATES 1/ 2/

(Dollars per metric ton)

Year	Gray portland cement	White portland cement	All portland cement	Prepared masonry cement	All classes of cement
1999	76.41	166.04	77.18	103.19	76.45 r/
2000	76.61	159.45	77.34	107.42	78.56

r/ Revised.

1/ Excludes Puerto Rico. Mill net value is the actual value of sales to customers, f.o.b. plant or import terminal, less all discounts and allowances, less any freight charges from U.S. producing plant to distribution terminal and to final customers.

2/ Although unrounded, the data incorporate estimates for some plants and are accurate to no better than two significant figures.

TABLE 15
PORTLAND CEMENT SHIPMENTS IN 2000, BY DISTRICT AND TYPE OF CUSTOMER 1/

(Thousand metric tons)

District 2/ 3/	Ready-mixed concrete	Concrete product manufacturers 4/	Contractors 5/	Building material dealers	Oil well, mining, waste 6/	Government and miscellaneous 7/	District total 8/ 9/
Maine and New York	2,686	378	73	195	--	89	3,422
Pennsylvania, eastern	3,099	1,103	197	323	--	110	4,832
Pennsylvania, western	971	163	157	29	3	90	1,412
Illinois	2,112	399	77	28	252	--	2,868
Indiana	2,306	443	61	105	13	5	2,932
Michigan	4,231	667	484	364	21	--	5,766
Ohio	943	124	56	48	2	--	1,174
Iowa, Nebraska, South Dakota	3,611	688	356	60	57	7	4,779
Kansas	1,313	121	205	30	20	4	1,693
Missouri	4,427	757	690	84	--	30	5,988
Florida	5,135	1,561	108	373	2	145	7,325
Georgia, Virginia, West Virginia	2,230	372	94	339	11	9	3,055
Maryland	1,217	267	132	40	--	18	1,675
South Carolina	2,106	409	43	82	1	21	2,661
Alabama	3,473	689	209	156	3	9	4,539
Kentucky, Mississippi, Tennessee	2,122	270	119	28	5	--	2,544
Arkansas and Oklahoma	1,778	208	607	22	35	9	2,659
Texas, northern	3,305	456	1,069	75	354	22	5,282
Texas, southern	3,732	601	700	153	385	36	5,608
Arizona and New Mexico	2,679	355	266	162	39	108	3,610
Colorado and Wyoming	1,970	233	253	91	34	--	2,581
Idaho, Montana, Nevada, Utah	2,173	258	233	33	81	188	2,965
Alaska and Hawaii	318	37	4	22	--	--	381
California, northern	3,019	374	172	172	--	12	3,749
California, southern	6,669	1,434	399	380	73	49	9,004
Oregon and Washington	1,724	227	137	72	--	64	2,225
Independent importers, n.e.c. 10/	5,301	870	225	84	14	55	6,552
Total 9/	74,655	13,465	7,127	3,548	1,406	1,082	101,282
Puerto Rico	791	204	117	552	--	1	1,665

-- Zero.

1/ Includes shipments of imported cement and cement ground from imported clinker. Data other than district totals are presented unrounded but incorporate estimates for some plants and are likely accurate to only two significant figures.

2/ District location is that of the reporting facility. Shipments may include material sold into other districts.

3/ Includes shipments by independent importers, where district assignations were possible.

4/ Shipments to concrete product manufacturers include brick-block—6,092; precast—3,127; pipe—1,710; and other or unspecified—2,740.

5/ Shipments to contractors include airport—444; road paving—4,816; soil cement—950; and other or unspecified—1,034.

6/ Shipments to oil well, mining, and waste include oil well drilling—1,168; mining—78; and waste stabilization—160.

7/ Includes shipments for which customer types were not specified.

8/ Shipments calculated based on an annual survey of plants and importers; may differ from tables 9 and 10, which are based on consolidated monthly data.

9/ Data may not add to totals shown because of independent rounding.

10/ Shipments by independent importers for which district assignations were not possible.

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TABLE 16
PORTLAND CEMENT SHIPPED FROM PLANTS IN THE UNITED STATES TO DOMESTIC CUSTOMERS, BY TYPE 1/

(Thousand metric tons)

Type	1999	2000
General use and moderate heat (Types I and II) (Gray)	90,891	90,644
High early strength (Type III)	3,297	3,815
Sulfate resisting (Type V)	3,046	4,453
Block	632	636
Oil well	578	1,039
White	848	894
Blended:		
Portland, natural pozzolans	230	194
Portland, granulated blast furnace slag	299	385
Portland, fly ash	319	405
Other blended cement 2/	345	313
Total 3/	1,193	1,296
Expansive and regulated fast setting	85	60
Miscellaneous 4/	175	111
Grand total 3/ 5/	100,746	102,947

1/ Includes imported cement. Includes Puerto Rico.
2/ Includes blends with cement kiln dust and silica fume.
3/ Data may not add to totals shown because of independent rounding.
4/ Includes waterproof and low heat (Type IV) varieties.
5/ Shipments are derived from an annual survey of plants and importers; may differ from tables 9 and 10, which are based on consolidated company monthly data.

TABLE 17
U.S. EXPORTS OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
Country of destination	Quantity	Value 2/	Quantity	Value 2/
Aruba	5	255	2	218
Bahamas, The	9	1,294	15	1,883
Belize	--	--	6	1,054
Brazil	3	207	5	452
Canada	533	37,795	581	41,161
China	2	72	2	105
Colombia	4	337	2	289
Costa Rica	1	97	6	801
Czech Republic	1	21	7	308
Dominican Republic	6	1,410	1	158
Germany	10	473	(3/)	8
Hong Kong	2	123	9	434
Indonesia	9	415	--	--
Lebanon	(3/)	3	5	262
Mexico	44	7,017	51	10,347
Panama	4	265	3	263
Philippines	(3/)	25	3	711
Russia	1	37	3	128
Saudi Arabia	3	127	2	175
Taiwan	7	325	2	113
Trinidad and Tobago	8	363	2	103
United Kingdom	(3/)	209	4	568
Venezuela	3	313	3	745
Other	41 r/	4,007 r/	24	3,918
Total 4/	694	55,190	738	64,204

See footnotes at end of table.

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TABLE 17–Continued
U.S. EXPORTS OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY 1/

r/ Revised. -- Zero.
1/ Includes portland and masonry cements.
2/ Free alongside ship (f.a.s.) value. The value of exports at the U.S. seaport or border point of export is based on the transaction price, including inland freight, insurance, and other charges incurred in placing the merchandise alongside the carrier. The value excludes the cost of loading.
3/ Less than 1/2 unit.
4/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

	1999			2000		
		Value			Value	
Country of origin	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Australia	388	8,520	15,079	180	4,305	7,384
Bahamas, The	--	--	--	206	7,506	9,485
Belgium	182	6,163	8,449	8	1,040	1,372
Bulgaria	264	10,161	13,129	635	26,301	33,691
Canada	5,511	280,812	303,271	4,948	268,875	285,040
China	3,836	123,507	163,169	3,451	107,852	143,945
Colombia	1,250	51,348	63,762	1,524	59,173	75,694
Croatia	23	5,115	5,727	64	7,097	8,453
Cyprus	81	3,044	3,712	--	--	--
Denmark	643	33,914	45,853	554	27,934	38,105
France	129	18,912	20,255	79	15,223	16,513
Greece	2,086	80,366	101,404	1,479	51,897	69,159
Indonesia	59	2,596	3,455	197	5,300	9,079
Italy	665	25,588	33,710	249	9,645	12,986
Korea, Republic of	1,529	43,200	67,045	1,823	49,742	75,578
Lebanon	--	--	--	108	4,167	4,935
Mexico	1,286	55,216	67,416	1,409	60,700	74,006
Morocco	177	6,800	8,956	22	974	1,331
Norway	332	12,125	15,227	263	10,257	12,626
Philippines	26	604	1,061	160	3,360	7,187
Spain	1,900	80,403	103,170	1,177	45,673	60,433
Sweden	791	26,777	34,463	903	28,879	37,694
Switzerland	54	1,915	2,878	--	--	--
Taiwan	39	672	1,068	82	2,417	3,745
Thailand	5,140	144,546	217,925	5,693	142,787	231,235
Turkey	767	30,575	37,760	1,453	47,868	69,273
United Kingdom	60	3,688	4,793	5	1,575	1,946
Venezuela	2,073	84,273	102,818	1,878	75,173	95,353
Other	62 r/	3,685 r/	4,269 r/	136	8,223	11,292
Total 4/	29,351	1,144,525	1,449,823	28,684	1,073,943	1,397,541

r/ Revised. -- Zero.
1/ Includes portland, masonry, and other hydraulic cements. Includes imports into Puerto Rico.
2/ Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.
3/ Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.
4/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

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TABLE 19
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1999			2000		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
Anchorage, AK:						
Canada	2	81	84	(3/)	12	14
China	88	3,113	4,497	94	2,875	4,197
Total 4/	90	3,194	4,582	95	2,887	4,211
Baltimore, MD:						
Colombia	64	2,905	4,108	141	5,645	8,043
Denmark	--	--	--	(3/)	32	40
Germany	(3/)	14	14	(3/)	291	336
Greece	--	--	--	199	7,273	10,334
Netherlands	(3/)	98	107	(3/)	96	105
Spain	--	--	--	15	474	834
Turkey	27	990	991	27	1,267	2,073
Venezuela	234	10,206	10,575	112	4,524	4,997
Total 4/	325	14,213	15,795	494	19,602	26,763
Boston, MA:						
Belgium	--	--	--	(3/)	69	72
Colombia	--	--	--	7	246	371
Netherlands	(3/)	138	146	(3/)	53	62
Norway	--	--	--	36	2,681	2,741
Spain	--	--	--	30	1,051	1,597
United Kingdom	--	--	--	(3/)	11	11
Venezuela	85	3,705	5,293	312	11,438	16,250
Total 4/	86	3,843	5,439	386	15,550	21,104
Buffalo, NY:						
Canada	626	32,195	33,928	546	29,548	31,133
Denmark	2	271	273	(3/)	10	10
United Kingdom	1	209	301	2	384	398
Total 4/	630	32,675	34,502	548	29,943	31,541
Charleston, SC:						
Australia	97	1,893	3,470	73	1,275	2,494
Canada	--	--	--	10	300	500
China	173	5,289	7,093	--	--	--
Colombia	6	234	322	101	3,932	5,337
Germany	--	--	--	(3/)	15	18
Greece	--	--	--	65	2,266	2,709
Indonesia	32	1,261	1,891	--	--	--
Korea, Republic of	--	--	--	36	1,075	1,558
Netherlands	--	--	--	(3/)	64	71
Spain	366	13,142	17,816	16	634	848
Sweden	14	300	360	--	--	--
Thailand	121	2,457	4,624	408	9,786	19,796
Turkey	--	--	--	204	6,178	11,806
United Kingdom	(3/)	151	198	1	370	463
Venezuela	21	876	1,085	--	--	--
Total 4/	830	25,602	36,860	915	25,895	45,601
Chicago, IL:						
Canada	--	--	--	34	1,902	1,992
Denmark	(3/)	2	4	--	--	--
India	--	--	--	(3/)	4	5
Japan	(3/)	25	27	(3/)	43	48
Total 4/	(3/)	28	31	35	1,949	2,046
Cleveland, OH:						
Canada	903	47,501	48,975	643	35,779	36,511
Spain	--	--	--	(3/)	2	3
United Kingdom	(3/)	60	83	1	221	285
Total 4/	903	47,560	49,058	644	36,002	36,799
Columbia-Snake, OR-WA, China	455	15,837	21,042	452	14,172	19,318
Detroit, MI:						
Canada	1,734	87,694	96,112	1,472	85,463	89,245
Denmark	(3/)	51	54	--	--	--
Germany	--	--	--	23	1,049	1,059

See footnotes at end of table.

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TABLE 19--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1999			2000		
	Quantity	Value		Quantity	Value	
		Customs 1/	C.i.f. 2/		Customs 1/	C.i.f. 2/
Detroit, MI--Continued:						
Korea, Republic of	--	--	--	102	4,509	4,549
Morocco	96	3,761	5,614	22	974	1,331
Thailand	160	7,241	7,311	--	--	--
United Kingdom	(3/)	170	214	--	--	--
Total 4/	1,991	98,916	109,305	1,619	91,994	96,183
Duluth, MN, Canada	362	17,956	20,764	263	14,028	16,007
El Paso, TX, Mexico	426	17,490	21,952	489	19,295	24,414
Great Falls, MT:						
Belgium	--	--	--	(3/)	10	11
Canada	166	7,313	9,014	16	888	1,095
Total 4/	166	7,313	9,014	16	898	1,106
Honolulu, HI:						
Australia	56	1,064	1,981	--	--	--
China	147	3,579	4,589	122	2,201	3,216
Thailand	66	1,062	1,721	144	2,460	3,898
Total 4/	270	5,704	8,292	266	4,661	7,115
Houston-Galveston, TX:						
Belgium	--	--	--	(3/)	12	13
China	27	698	1,175	(3/)	37	45
Colombia	111	4,652	6,804	136	5,738	8,483
Croatia	--	--	--	18	612	965
Denmark	26	964	1,261	28	769	1,135
France	(3/)	93	102	(3/)	269	295
Germany	--	--	--	(3/)	75	86
Greece	290	10,593	14,182	104	3,347	4,658
India	--	--	--	(3/)	3	4
Indonesia	--	--	--	15	488	527
Japan	(3/)	45	56	(3/)	16	22
Korea, Republic of	1,513	42,531	66,135	1,609	41,700	66,232
Mexico	15	456	694	--	--	--
Peru	--	--	--	26	796	1,191
Philippines	26	604	1,061	--	--	--
Spain	287	11,136	13,567	--	--	--
Thailand	504	11,149	18,723	531	12,595	18,913
Turkey	56	2,214	3,190	513	14,827	21,440
United Arab Emirates	--	--	--	43	3,467	5,372
United Kingdom	31	816	1,357	(3/)	79	150
Venezuela	42	1,793	2,263	18	755	873
Total 4/	2,928	87,746	130,571	3,043	85,584	130,405
Laredo, TX, Mexico	137	15,413	16,117	159	17,861	18,621
Los Angeles, CA:						
Australia	(3/)	7	8	(3/)	4	5
China	1,690	54,905	70,357	1,475	47,719	61,992
Germany	(3/)	3	4	--	--	--
India	--	--	--	(3/)	4	5
Japan	29	1,097	1,328	33	1,001	1,324
Mexico	(3/)	8	9	--	--	--
Taiwan	--	--	--	(3/)	3	4
Thailand	--	--	--	85	2,386	3,541
United Arab Emirates	(3/)	12	15	--	--	--
United Kingdom	(3/)	18	20	(3/)	13	16
Total 4/	1,719	56,049	71,741	1,593	51,131	66,886
Miami, FL:						
Belgium	4	488	517	3	534	566
China	165	4,184	6,377	--	--	--
Colombia	11	553	703	3	318	403
Denmark	59	2,042	2,651	104	3,114	4,484
France	--	--	--	(3/)	5	6
Indonesia	--	--	--	20	662	896
Korea, Republic of	--	--	--	43	1,392	1,829

See footnotes at end of table.

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TABLE 19--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1999			2000		
	Quantity	Value		Quantity	Value	
		Customs 1/	C.i.f. 2/		Customs 1/	C.i.f. 2/
Miami, FL--Continued:						
Mexico	5	450	529	5	446	568
Spain	889	40,803	52,077	776	31,763	40,768
Sweden	518	16,712	21,447	849	27,148	35,378
Thailand	55	1,359	2,092	18	600	840
United Kingdom	(3/)	80	102	(3/)	137	177
Venezuela	190	7,829	10,024	138	4,995	6,627
Total 4/	1,896	74,501	96,519	1,960	71,113	92,544
Milwaukee, WI:						
Canada	50	2,801	3,401	80	4,598	4,958
Croatia	--	--	--	18	468	468
Total 4/	50	2,801	3,401	99	5,066	5,426
Minneapolis, MN, Germany	(3/)	6	8	(3/)	--	--
Mobile, AL:						
Australia	70	1,172	2,410	--	--	--
Colombia	25	1,054	1,054	--	--	--
Greece	--	--	--	32	1,020	1,339
Indonesia	28	1,336	1,564	--	--	--
Taiwan	24	342	423	--	--	--
Thailand	293	6,171	10,747	459	9,443	18,322
Turkey	--	--	--	66	1,522	2,346
Total 4/	440	10,074	16,197	557	11,985	22,006
New Orleans, LA:						
Belgium	172	5,210	7,133	--	--	--
Bulgaria	130	5,093	6,652	344	12,530	17,489
China	25	577	615	2	155	204
Colombia	--	--	--	(3/)	9	11
Croatia	22	4,921	5,516	27	5,976	6,977
Cyprus	27	1,154	1,490	--	--	--
France	12	2,239	2,600	13	2,435	2,798
Greece	797	30,989	38,338	327	11,278	14,692
Italy	649	24,904	32,969	244	8,993	12,159
Lebanon	--	--	--	45	1,713	2,325
Sweden	259	9,765	12,657	26	830	1,115
Thailand	2,859	80,942	124,384	2,524	64,692	100,247
Turkey	146	7,833	9,232	290	11,773	14,909
Venezuela	231	9,515	11,885	429	18,949	22,812
Total 4/	5,330	183,144	253,469	4,271	139,333	195,738
New York City, NY:						
Bahamas, The	--	--	--	206	7,506	9,485
Colombia	(3/)	6	10	(3/)	11	17
Croatia	(3/)	151	168	(3/)	40	42
Denmark	170	10,459	12,051	68	4,359	5,150
Germany	--	--	--	(3/)	16	17
Greece	394	14,828	18,958	350	12,402	16,791
India	--	--	--	(3/)	5	6
Lebanon	--	--	--	(3/)	3	4
Liechtenstein	(3/)	16	17	--	--	--
Netherlands	(3/)	166	180	(3/)	88	100
Norway	332	12,125	15,227	227	7,576	9,885
Sweden	--	--	--	28	901	1,201
Turkey	265	9,567	11,180	300	10,533	14,185
United Kingdom	(3/)	72	84	(3/)	98	109
Venezuela	28	1,076	1,188	34	1,248	1,778
Total 4/	1,188	48,465	59,064	1,214	44,787	58,770
Nogales, AZ:						
Mexico	656	19,725	25,879	718	21,418	28,124
Netherlands	--	--	--	(3/)	17	21
Total 4/	656	19,725	25,879	718	21,434	28,145

See footnotes at end of table.

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TABLE 19--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1999			2000		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
Norfolk, VA:						
Bulgaria	109	4,092	5,401	291	13,771	16,202
China	--	--	--	(3/)	2	2
Denmark	223	8,857	11,841	(3/)	67	88
France	90	15,768	16,502	65	12,471	13,361
Germany	--	--	--	(3/)	9	11
Greece	464	19,246	23,647	402	14,311	18,636
Indonesia	--	--	--	38	1,098	1,695
Netherlands	(3/)	34	36	(3/)	185	196
United Kingdom	2	516	629	1	208	261
Venezuela	8	248	337	--	--	--
Total 4/	896	48,761	58,394	798	42,122	50,453
Ogdensburg, NY:						
Canada	178	6,637	7,033	192	7,355	7,720
Croatia	(3/)	42	44	--	--	--
Total 4/	178	6,679	7,077	192	7,355	7,720
Pembina, ND, Canada	341	16,917	19,044	344	16,830	18,770
Philadelphia, PA:						
Germany	1	605	720	(3/)	310	348
Italy	--	--	--	4	560	700
Thailand	339	7,448	8,974	499	9,840	14,342
United Kingdom	(3/)	22	24	(3/)	7	8
Total 4/	340	8,075	9,718	503	10,717	15,399
Port Arthur, TX, Thailand	30	539	539	--	--	--
Portland, ME:						
Canada	66	5,988	6,171	68	6,445	6,812
Saudi Arabia	25	934	934	--	--	--
Turkey	--	--	--	46	1,090	1,761
Total 4/	92	6,922	7,105	114	7,535	8,574
Providence, RI:						
Colombia	24	956	1,373	15	513	727
Philippines	--	--	--	143	2,984	6,501
Spain	247	11,142	14,562	268	9,465	13,724
Venezuela	73	2,936	3,929	137	4,945	7,146
Total 4/	345	15,034	19,863	562	17,907	28,098
San Diego, CA:						
China	551	18,443	24,014	709	21,724	28,464
Mexico	45	1,446	1,888	30	1,001	1,310
Thailand	--	--	--	1	98	127
Total 4/	596	19,890	25,902	739	22,823	29,902
San Francisco, CA:						
Canada	--	--	--	12	579	672
China	354	11,315	16,343	421	13,018	18,628
Switzerland	16	654	1,203	--	--	--
Taiwan	--	--	--	82	2,415	3,742
Thailand	407	18,562	26,203	321	14,385	20,427
United Kingdom	--	--	--	(3/)	3	6
Total 4/	777	30,531	43,750	835	30,398	43,475
San Juan, PR:						
Belgium	6	464	799	5	415	710
Bulgaria	25	977	1,077	--	--	--
China	--	--	--	134	4,685	6,111
Colombia	13	851	878	31	1,142	1,240
Cyprus	54	1,890	2,222	--	--	--
Denmark	33	1,974	3,503	202	8,105	11,512
France	26	812	1,051	--	--	--
Italy	16	677	730	(3/)	8	9
Japan	(3/)	97	144	--	--	--
Lebanon	--	--	--	63	2,451	2,606
Mexico	3	229	347	7	679	968
Morocco	80	3,039	3,342	--	--	--

See footnotes at end of table.

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TABLE 19--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1999			2000		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
San Juan, PR--Continued:						
Spain	34	1,170	1,233	7	204	214
Thailand	40	640	1,390	--	--	--
Turkey	111	3,843	5,090	--	--	--
Venezuela	168	5,395	6,040	--	--	--
Total 4/	609	22,058	27,847	450	17,688	23,369
Savannah, GA:						
Australia	33	574	1,166	--	--	--
China	5	180	231	--	--	--
Colombia	49	2,301	2,926	24	1,295	1,351
Denmark	18	1,594	2,332	5	366	507
Indonesia	--	--	--	82	1,484	3,642
Italy	(3/)	6	11	(3/)	76	108
Taiwan	15	330	645	--	--	--
Thailand	129	3,422	5,240	132	2,988	5,244
Turkey	--	--	--	6	679	754
United Kingdom	25	1,574	1,779	(3/)	45	61
Venezuela	87	3,689	4,063	69	2,746	2,805
Total 4/	362	13,670	18,393	318	9,679	14,471
Seattle, WA:						
Australia	132	3,810	6,044	106	3,027	4,885
Canada	833	40,654	42,182	1,077	51,724	55,005
China	126	4,449	5,618	44	1,264	1,767
Japan	1	238	344	(3/)	33	48
Total 4/	1,090	49,152	54,188	1,227	56,048	61,705
St. Albans, VT:						
Canada	250	15,076	16,564	178	13,084	14,018
France	--	--	--	(3/)	44	53
Total 4/	250	15,076	16,564	178	13,128	14,071
Tampa, FL:						
Canada	--	--	--	12	340	588
China	28	938	1,217	--	--	--
Colombia	946	37,835	45,584	1,054	39,767	48,961
Denmark	112	7,700	11,882	146	11,112	15,178
Greece	141	4,710	6,278	--	--	--
India	--	--	--	(3/)	8	10
Indonesia	--	--	--	20	650	880
Korea, Republic of	--	--	--	33	1,066	1,410
Philippines	--	--	--	16	376	687
Spain	79	3,010	3,914	64	2,081	2,444
Switzerland	38	1,261	1,675	--	--	--
Thailand	136	3,555	5,978	551	12,400	23,866
Turkey	161	6,128	8,077	--	--	--
United Arab Emirates	--	--	--	5	409	617
Venezuela	752	30,765	37,918	558	21,423	27,154
Total 4/	2,395	95,902	122,523	2,458	89,632	121,795
U.S. Virgin Islands:						
Barbados	--	--	--	2	74	94
Panama	5	156	187	3	92	117
Venezuela	53	1,964	2,357	71	4,149	4,911
Total 4/	57	2,120	2,543	75	4,315	5,122
Washington, DC, Italy	--	--	--	(3/)	5	6
Wilmington, NC:						
Colombia	--	--	--	13	557	750
Indonesia	--	--	--	21	918	1,438
Italy	--	--	--	(3/)	4	4
Korea, Republic of	16	669	910	--	--	--
Thailand	--	--	--	22	1,114	1,670
Venezuela	103	4,275	5,861	--	--	--
Total 4/	118	4,944	6,771	55	2,593	3,864
Grand total 4/	29,351	1,144,525	1,449,823	28,684	1,073,943	1,397,541

See footnotes at end of table.

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TABLE 19--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

-- Zero.
1/ Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.
2/ Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.
3/ Less than 1/2 unit.
4/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

TABLE 20
U.S. IMPORTS FOR CONSUMPTION OF GRAY PORTLAND CEMENT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

	1999			2000		
		Value			Value	
Country	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Australia	228	5,703	9,514	179	4,301	7,379
Bahamas, The	--	--	--	199	6,713	8,553
Belgium	74	2,605	3,463	--	--	--
Bulgaria	238	9,185	12,053	635	26,301	33,691
Canada	4,057	202,552	217,108	3,916	202,885	216,312
China	3,678	119,504	157,973	3,301	104,103	138,811
Colombia	1,096	45,329	56,701	1,314	51,444	66,633
Croatia	--	--	--	18	612	965
Cyprus	27	1,154	1,490	--	--	--
Denmark	438	16,861	21,960	385	12,721	17,756
Greece	1,843	71,910	90,203	1,392	48,417	64,535
Indonesia	56	1,852	2,584	161	3,894	7,113
Italy	665	25,529	33,625	248	9,557	12,863
Korea, Republic of	1,529	43,200	67,045	1,721	45,232	71,029
Mexico	1,080	31,948	42,586	1,174	34,282	45,756
Norway	332	12,125	15,227	226	7,576	9,885
Philippines	26	604	1,061	159	3,360	7,187
Spain	1,795	70,193	91,577	1,054	35,535	48,253
Sweden	789	26,387	33,949	903	28,879	37,694
Taiwan	15	330	645	81	2,417	3,745
Thailand	3,089	91,438	139,770	3,594	100,413	156,533
Turkey	767	30,575	37,760	1,225	40,632	59,230
United Kingdom	48	1,563	2,135	(3/)	33	37
Venezuela	1,725	72,309	88,758	1,851	73,376	93,495
Other	75 r/	2,861 r/	3,674 r/	106	3,672	4,723
Total 4/	23,672	885,716	1,130,861	23,842	846,355	1,112,178

r/ Revised. -- Zero.
1/ Includes imports into Puerto Rico.
2/ The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.
3/ Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.
4/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

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TABLE 21
U.S. IMPORTS FOR CONSUMPTION OF WHITE CEMENT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999			2000		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Belgium	10	952	1,316	8	949	1,276
Canada	210 r/	22,725 r/	23,447 r/	181	21,118	21,892
China	5	202	327	26	1,359	1,674
Colombia	2	265	337	9	880	1,042
Denmark	205	17,054	23,893	170	15,211	20,343
Indonesia	3	744	871	36	1,406	1,966
Mexico	183	21,267	22,555	205	23,807	25,352
Norway	--	--	--	36	2,681	2,741
Spain	105	10,206	11,586	123	10,136	12,176
Thailand	80	9,663	14,523	23	1,212	1,798
Turkey	--	--	--	24	1,976	2,340
United Arab Emirates	--	--	--	48	3,876	5,988
United Kingdom	8	793	960	(4/)	17	18
Venezuela	15	635	836	22	1,560	1,612
Other	(4/)	263	287 r/	14	1,686	1,960
Total 5/	825 r/	84,769 r/	100,939 r/	923	87,872	102,178

r/ Revised. -- Zero.
1/ Includes imports into Puerto Rico.
2/ Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.
3/ Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.
4/ Less than 1/2 unit.
5/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

TABLE 22
U.S. IMPORTS FOR CONSUMPTION OF CLINKER, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999			2000		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Australia	159	2,810	5,557	--	--	--
Canada	1,221	53,203	60,268	847	43,552	45,459
China	153	3,776	4,843	122	2,282	3,321
Colombia	151	5,754	6,723	201	6,849	8,019
Croatia	--	--	--	18	468	468
Cyprus	54	1,890	2,222	--	--	--
France	127	17,853	19,112	76	13,177	14,312
Greece	141	4,710	6,278	--	--	--
Korea, Republic of	--	--	--	102	4,509	4,549
Lebanon	--	--	--	90	3,593	4,097
Morocco	177	6,800	8,956	22	974	1,331
Switzerland	39	1,261	1,675	--	--	--
Thailand	1,971	43,445	63,632	2,077	41,163	72,904
Turkey	--	--	--	204	5,261	7,703
Venezuela	328	11,014	12,883	--	--	--
Other	49 r/	1,319 r/	1,500 r/	(4/)	3	3
Total 5/	4,570 r/	153,834	193,650	3,760	121,830	162,167

See footnotes at end of table.

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TABLE 22--Continued
U.S. IMPORTS FOR CONSUMPTION OF CLINKER, BY COUNTRY 1/

r/ Revised. -- Zero.
1/ For all types of hydraulic cement. Includes imports into Puerto Rico.
2/ Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.
3/ Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.
4/ Less than 1/2 unit.
5/ Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

TABLE 23
HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Afghanistan e/	116	116	116	116	120
Albania e/	203 r/	100 r/	84 r/	106 r/	110
Algeria e/	6,500 r/	7,096 2/	7,500 r/	7,500	8,300
Angola e/	270	301 2/	350	350	350
Argentina	5,117	6,858	7,091	7,187	7,150
Armenia	282	297	300	287 r/	219 2/
Australia e/	6,250 r/	6,450 r/	6,850 r/	7,450 r/	7,500
Austria	3,874	3,852	3,850 e/	3,950 e/	3,900
Azerbaijan	223	315	201	200	200
Bahrain	192	172	230	156 r/	89 2/
Bangladesh e/ 3/	650	865	900	950	980
Barbados	107	173	259	253 r/	268 2/
Belarus	1,467	1,876	2,035	2,100 r/	1,800 2/
Belgium	7,857	8,052	7,000 r/ e/	7,500 r/ e/	8,000
Benin e/	360	450	520	520	520
Bhutan e/	160	160	150	150	150
Bolivia	934	1,035	1,169 r/	1,214 r/	1,300
Bosnia and Herzegovina e/	150	200	300	300	300
Brazil	34,597	38,096	39,942	40,270	39,208 p/
Brunei	250 r/ e/	250 r/ e/	216	208 r/	232 2/
Bulgaria	2,137	1,656	1,700 e/	1,700 e/	1,700
Burkina Faso e/	30	40	40	50	50
Burma	505	516	365	338	393 2/
Cambodia e/	200	200	300	300	300
Cameroon	305	350	400	500 e/	500
Canada	11,587	12,015	12,124	12,634 r/	12,612 p/
Chile	3,634	3,735	3,888	3,036 r/	3,491
China	491,190	511,730	536,000	573,000	583,190 2/
Colombia	8,907	8,446	9,190	7,500 r/ e/	7,500
Congo (Brazzaville)	50 e/	20 r/	--	--	20
Congo (Kinshasa)	241	125	134 r/	158 r/	96
Costa Rica	830	940	1,200 r/	1,260 r/	1,150
Côte d'Ivoire e/	1,000	1,100	650	650	650
Croatia	1,842	2,134	2,295	2,712	2,852 2/
Cuba	1,453	1,713	1,800 e/	1,920 r/	1,700
Cyprus e/	1,000	910	1,200 2/	1,200	1,200
Czech Republic	5,015	4,877	4,604	4,241 r/	4,093 2/
Denmark	2,629	2,683	2,528	2,600 r/ e/	2,650
Dominican Republic	1,642	1,835	1,885	2,000 e/	2,000
Ecuador	3,028	2,900 e/	2,600 r/	2,300 r/	2,800
Egypt	18,700	19,700	21,000 e/	23,313 r/	24,143 2/
El Salvador	948	1,020	1,076 r/	1,031 r/	1,064 2/
Eritrea e/	47 2/	60 r/	50 r/	50 r/	45
Estonia	388	423	321	358	329 2/
Ethiopia e/	690	752	784	638 r/	880 2/

See footnotes at end of table.

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TABLE 23--Continued
HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Fiji	84	96	90	95 e/	95
Finland	975	905	903 e/	1,310 r/	1,350
France	19,514	19,780	19,500 e/	19,527	20,000
French Guiana	52	51	50 e/	50 e/	50
Gabon	185	200 e/	196	200 e/	200
Georgia	85	91	200	300	300 2/
Germany	31,533	35,945	36,610	38,099	38,000
Ghana	1,500 e/	1,700 e/	1,630	1,870	1,950 2/
Greece e/	14,700	14,982 2/	15,000	14,000 r/	14,500
Guadeloupe e/	230	230	230	230	230
Guatemala	1,090	1,280	1,770 r/	1,900 r/	2,000
Guinea e/	260	260	260	250	250
Honduras	952	980 e/	1,020 r/	1,200 r/	1,280
Hong Kong	2,027	1,925	1,539	1,387	1,284 2/
Hungary	2,747	2,811	2,999	2,979 r/	3,000
Iceland	88	101	118 r/	131 r/	144 2/
India e/	75,000	80,000	85,000	90,000	95,000
Indonesia	24,646	27,505	22,341	23,925	27,789 2/
Iran	18,350	19,250	19,500 e/	20,000 e/	20,000
Iraq e/	1,600	1,700	2,000	2,000	2,000
Ireland	1,933	2,100	2,000 e/	2,000 e/	2,000
Israel	5,600 r/	5,400 e/	6,476 r/	6,354 r/	6,600
Italy	33,327	33,721	35,512	36,000 e/	36,000
Jamaica	557	588	558	504	500
Japan	94,492	91,938	81,328	80,120	81,300
Jordan	3,512 r/	3,251 r/	2,650 r/	2,687 r/	2,640 2/
Kazakhstan	1,120	661 e/	600 e/	838 r/	1,175 2/
Kenya	1,816	1,506	1,200 e/	1,204 r/	1,071 2/
Korea, North e/	17,000	17,000	17,000	16,000	15,000
Korea, Republic of	58,434	60,317	46,091	48,157	51,255 2/
Kuwait e/	2,000	2,000	2,000	2,000	2,000
Kyrgyzstan	544	658	709	386	500 2/
Laos e/	78 r/	84 r/	80 r/	80 r/	80
Latvia	325	246	W	W	W
Lebanon	3,500 r/ e/	2,703	3,310 r/	3,200 r/	3,200
Liberia e/	15	7	10	15	15
Libya	3,550	2,524	3,000 e/	3,000 e/	3,000
Lithuania	700 r/ e/	714 r/	788	666	570 2/
Luxembourg	667	683	700 e/	700 e/	700
Macedonia	491	500 e/	461	520	585 2/
Madagascar	44 r/	36 r/	44 r/	46 r/	48
Malawi	91	176	134 r/	187 r/	198
Malaysia	12,349	12,668	10,397	10,104 r/	11,445 2/
Mali e/	12	10	10	10	10
Martinique e/	220	220	220	220	220
Mauritania e/	100	80	50	50	50
Mexico	25,366	27,548	27,744	29,413	31,677 2/
Moldova	40	122	74	50	222 2/
Mongolia	106	112	109	104	92 2/
Morocco	6,585	7,236	7,200 e/	7,200 e/	7,200
Mozambique	180 e/	220 e/	260 r/	270 r/	310
Namibia e/	50	100	150	150	150
Nepal 3/	309	225	280 e/	290 e/	300
Netherlands	3,140	3,230	3,200 e/	3,200 e/	3,200
New Caledonia	100 e/	100 e/	--	--	100
New Zealand	974	976	950 r/ e/	960 r/ e/	950
Nicaragua	360	377	480 r/	570 r/	650
Niger e/	29 2/	30	30	30	30
Nigeria	2,545	2,520	2,700 e/	2,500 e/	2,500
Norway	1,664	1,724	1,676	1,700 e/	1,720
Oman	1,260	1,264	1,300 e/	1,300 e/	1,716 2/
Pakistan	8,900 e/	9,001	8,901	9,300 e/	9,500
Panama	647	700	750	900 r/	1,000

See footnotes at end of table.

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TABLE 23--Continued
HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Paraguay	613	675 e/	620 r/	640 r/	650
Peru	3,848	4,301	4,340	3,799	3,800
Philippines	12,429	14,681	12,888	12,556	12,500
Poland	13,959	15,003	14,970	15,550 r/	14,807 2/
Portugal	8,455	9,395	9,500 e/	9,500 e/	9,200
Qatar	690	692	700 e/	1,025 r/	1,050
Réunion	299	277	380 r/	380 r/	400
Romania	6,956	7,298	7,300	6,252	8,264 2/
Russia	27,800	26,700	26,000	28,400	32,400 2/
Rwanda	42 r/	60 r/	59 r/	66 r/	70
Saudi Arabia	16,437	15,400	14,000 r/ e/	14,000 e/	15,000
Senegal	811	854	1,000	1,000 e/	1,000
Serbia and Montenegro	2,205	2,011	2,253	1,575	2,117 2/
Sierra Leone e/	160	50	100	100	100
Singapore e/	3,300	3,300	3,300	3,250	3,250
Slovakia	2,802	3,017	3,000 e/	3,000 e/	3,000
Slovenia	1,026	1,113	1,149	1,224 r/	1,300
South Africa e/	9,000	9,500	9,500	8,900	8,900
Spain (including Canary Islands)	25,157	27,632	27,943	30,800	30,000
Sri Lanka	928 e/	965 e/	874 r/	976 r/	1,008 2/
Sudan	380 e/	291	206 r/	267 r/	300
Suriname e/	60	65	65	65	65
Sweden	2,447	2,253	2,105	2,100 e/	2,150
Switzerland	3,638	3,568	3,600 e/	3,600 e/	3,600
Syria	4,500 e/	4,840 r/	4,607 r/	4,781 r/	4,830
Taiwan	21,537	21,522	19,652	18,283	18,500
Tajikistan	50	36	18	30	50 2/
Tanzania	726 r/	621 r/	778 r/	833 r/	833
Thailand	38,749 r/	37,086 r/	30,000 r/ e/	34,000 r/ e/	32,000
Togo	413	421	565	560	560
Trinidad and Tobago	617	653	690	688	743 2/
Tunisia	4,567	4,424 r/	4,588 r/	4,864 r/	5,409 2/
Turkmenistan e/	451 2/	450	450	450	450
Turkey	35,214	36,035	38,200	34,258 r/	35,825 2/
Uganda	250 r/	270 r/	285 r/	310 r/	320
Ukraine	5,017	5,098	5,591	5,828	5,311 2/
United Arab Emirates e/	6,000	5,250	6,000	6,000	6,000
United Kingdom	12,214	12,638	12,409	12,697 r/	12,800
United States (including Puerto Rico) 4/	80,818	84,255	85,522	87,777	89,510 2/
Uruguay	685	781	750 r/	720 r/	700
Uzbekistan	3,300	3,300	3,400 e/	3,300 e/	3,400 2/
Venezuela	7,556	8,145 r/	8,202 r/	8,500 r/ e/	8,600
Vietnam	6,586	8,019	9,700 r/	10,381 r/	12,500
Yemen	1,028	1,235	1,201	1,454	1,400
Zambia	348	384	351	300 r/ e/	380
Zimbabwe e/	1,000	1,100	1,100	1,000	1,000
Total 5/	1,493,000 r/	1,547,000	1,547,000 r/	1,603,000 r/	1,643,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing proprietary data. -- Zero.

1/ Table includes data available through August 20, 2001. Data may include clinker exports for some countries.

2/ Reported figure.

3/ Data for year ending June 30 of that stated.

4/ Portland and masonary cements only.

5/ Data are rounded to four significant digits.

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CHROMIUM

By John F. Papp

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production tables were prepared by Ronald L. Hatch and Glenn J. Wallace, international data coordinators.

In 2000, the U.S. chromium supply (measured in contained chromium) was 139,000 metric tons (t) from recycled stainless steel scrap; 453,000 t from imports; and 924,000 t from Government and industry stocks. Supply distribution was 86,300 t to exports; 840,000 t to Government and industry stocks; and 589,000 t to apparent consumption. Chromium apparent consumption increased by 5.63% compared with that of 1999.

Legislation and Government Programs

The Department of Health and Human Services (HHS) updated the toxicological profile for chromium. HHS revises and republishes toxicological profiles as necessary, but no less than once every 3 years. The profiles are prepared for health professionals and report toxicologic and health effect information (Syracuse Research Corp., 2000).

The Defense Logistics Agency (DLA) disposed of chromium materials under its fiscal year (FY) 2000 (October 1, 1999, through September 30, 2000) Annual Materials Plan (AMP). DLA's FY 2000 AMP (as revised in April) set maximum disposal goals for chromium materials at 90,700 t of chemical grade chromite ore, 227,000 t of metallurgical grade chromite ore, 90,700 t of refractory grade chromite ore, 136,000 t of chromium ferroalloys, and 454 t of chromium metal. DLA also developed its FY 2001 AMP, which set maximum disposal goals of 90,700 t of chemical grade chromite ore; 227,000 t of metallurgical grade chromite ore; 90,700 t of refractory grade chromite ore; 136,000 t of chromium ferroalloys; and 454 t of chromium metal (U.S. Department of Defense, 2001, p. 8, 11).

World Review

Albania.—The Government of Albania (GOA) studied the possibility of privatizing chromite ore mines and ferrochromium smelters (Ryan's Notes, 2000j). GOA contracted Darfo S.p.A. (Italy) to operate the Elbasan ferrochromium smelter. There are two 9 megavoltampere furnaces at the smelter, of which one is producing at the rate of 800 tons per month (t/mo) and the other is closed. Darfo planned to install a 13 megavoltampere and a 25 megavoltampere furnace at a cost of about $15 million, raising the plant's annual production capacity to 40,000 t (Ryan's Notes, 2000a).

Australia.—Danelagh Resources Pty. Ltd. produced chromite at Coobina Chromite Deposit 57 kilometers (km) east-southeast of Newman, Western Australia. The Coobina Range consists of a central core of serpentine. An associated gabbro was formed by the serpentinization of layered peridotite, which contains minor amounts of chlorite, talc, carbonate, chromite, and magnetite. As of December 1997, resources were: measured, 39,000 t graded at 38.5% chromic oxide; indicated, 86,200 t graded at 39.7% chromic oxide; and inferred, 400,000 t of similar grade. Mining process is open cut, and run-of-mine ore is crushed and screened. Danelagh exercised its option to take ownership of the mine leaving Consolidated Minerals

Chromium in the 20th Century

In 1900, "chromic iron ore" was used to describe what we now call chromite ore. Chromium was used as an alloying element, in chemical compounds, and in refractory materials. It played an important role in metallurgy as an alloying element. Chromium and tungsten were being alloyed with iron to make tool steels that permitted large increases in industrial productivity. Chromium was also used to make armor plating hard. These, along with the use of chromite ore as a refractory in steel-producing furnaces, made chromium a critical and strategic material during World War I. In 1900, the United States had resumed production of chromite ore and chromium after a hiatus from 1897 to 1899. Prior to that, the United States had produced 3,767 metric tons of chromite ore in 1890. Production picked up during World War I and again during World War II. In 1900, U.S. chromite ore production was 142 metric tons, which represented 0.27% of world production.

Chromium has played an important role in metallurgy as an alloying element. It was not until 1910 to 1920 that the alloying role of chromium with iron to make stainless steel was developed in France, Germany, the United Kingdom, and the United States. Once this was understood, however, stainless steel became an integral part of the steel industry, accounting for more than 2% of steel production in 2000. Stainless steel manufacture, while small compared with steel production of all grades, nonetheless accounts for about 60% of chromium consumption. Stainless steel, which didn't even exist in 1900, accounted for most of the chromium consumed in 2000, and its share of steel production was growing. Chromium chemical use has grown since 1900; chromite refractory use, however, has been reduced because of technological developments. Superalloys, which are engineering alloys of chromium and nickel used in aggressive environments and were also nonexistent in 1900, were an important strategic use of chromium in 2000, because they were used to make the internal workings of jet engines.

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Ltd.'s interest to a royalty. Chromite ore production was 6,000 t in 1996; 31,000 t in 1997; 130,000 t in 1998; and 85,000 t in 1999 (Resource Information Unit, 2000, p. 294-295). Danelagh planned to construct a beneficiation plant that would permit it to increase its recoverable resources and to produce more product grades. Danelagh reported proven reserves of 2.2 million tons (Mt) and probable reserves of 10 Mt. The mine produced chromite ore graded at 37% Cr_2O_3 and from 6 millimeters (mm) to 150 mm in size (Ryan's Notes, 2001c).

Tata Iron and Steel Co. Ltd. (India) studied the possibility of constructing a ferrochromium smelter in Gladstone, Queensland. Tata produced chromite ore and ferrochromium in India; however, its ferrochromium production was limited by the availability and cost of electrical power in India. Electrical power was available at a lower cost in Australia than it was in India. A 120,000-ton-per-year (t/yr) capacity ferrochromium smelter with the potential to double that capacity would cost about $50 million (Metal Bulletin, 2000o, 2001; Ryan's Notes, 2001b).

Dragon Mining NL studied the Range Well deposit 67 km northwest of Cue, Western Australia. Chromium occurs predominantly in the iron oxide minerals hematite and goethite. The Range Well laterite resource lies directly over part of a 5.5 km thick funnel-shaped layered ultramafic complex. As of June 1998, inferred resource was estimated at 36 Mt graded at 3.60% chromium (2% cutoff grade) (Resource Information Unit, 2000, p. 295).

Brazil.—Brazil reported production for use in the metallurgical and refractory industries. Brazil produced high- and low-carbon ferrochromium. Brazil reported 1999 chromite ore production of 420,000 t (45.2% Cr_2O_3), exported 194,000 t of chromite ore (53.1% Cr_2O_3), and imported 8,482 t (48.0% Cr_2O_3). In 1999, Brazil produced 91,000 t of chromium ferroalloys of which 71,000 t was high-carbon ferrochromium, 8,200 t was low-carbon ferrochromium, and the remainder was ferrochromium-silicon. Brazil imported 5,000 t of chromium ferroalloys and metal and exported 59 t of ferrochromium (Cesar, 2000).

Associação Brasileira dos Produtores de Ferroligas e de Silício Metálico reported ferrochromium production in 1999 to have been 71,291 t of high-carbon and 7,583 t of low-carbon ferrochromium. Brazil exported 59 t of high-carbon ferrochromium and 168 t of low-carbon ferrochromium. Brazil imported 2,144 t of high-carbon ferrochromium and 2,827 t of low-carbon ferrochromium (TEX Report, 2000r, s, t).

Villa Nova Mine, Amapa State, operated with an annual production capacity of 200,000 t of chromite concentrate from 400,000 t of run-of-mine chromite ore. Villa Nova operated a four-stage beneficiation process that it is replacing with a three-stage spiral separator process having a through-put of 100 metric tons per hour. The new process was expected to achieve a recovery rate of about 96% (Mining Weekly, 2000).

Canada.—Allican Resources planned to build a low-carbon ferrochromium smelter at Thetford Mines, Quebec. The project was estimated to cost about $44.6 million for a 19,000-metric-ton-year smelter. Chromite ore would be supplied initially from imports followed by development of chromite ore deposits in the Thetford area. At this capacity, the plant could supply about one-half of North American low-carbon ferrochromium demand (Ryan's Notes, 2000c).

China.—China reported its national chromium-material trade statistics for 1999. Chromite ore imports were 711,493 t in 1998; 816,229 t in 1999; and 1,112,838 t in 2000. High-carbon ferrochromium exports were 74,849 t in 1997; 65,576 t in 1998; 49,652 t in 1999; and 130,446 t in 2000. Low-carbon ferrochromium exports were 27,220 t in 1997; 36,508 t in 1998; 24,161 t in 1999; and 24,161 t in 2000 (TEX Report, 2000b, c, 2001a, b). Based on this reported trade, apparent consumption of chromium in China was 420,000 t.

The State Economic and Trade Commission of China embarked on a modernization program for the ferroalloys industry. Goals of the plan are to scrap old ferroalloy plants, prohibit construction of new plants, prevent environmental pollution, and promote technology. China operated about 1,600 ferroalloy furnaces of which about 1,000 had electrical power capacity under 3,000 kilovolt-amperes. Electrical furnaces rated under 1,800 kilovolt-amperes were to have been scrapped by the end of 2000; furnaces under 3,200 kilovolt-amperes by the end of 2001. New furnace construction was suspended until 2005 as were expansions. The modernization plan was expected to reduce high-carbon ferrochromium production in China; however, more low-carbon ferrochromium could be produced (TEX Report, 2000d).

European Union.—The European Union (EU) permits duty-free importation of ferrochromium from non-EU countries on a specified amount of material from all non-EU sources. Import duties are applied to imported materials in excess of the specified amount of material. The EU set the duty-free ferrochromium import quota at 1.035 Mt in January 2000 (Metal Bulletin, 2000a). The EU lifted antidumping duties imposed on Kazakhstani and Russian low-carbon ferrochromium producers in 1993 (Metal Bulletin, 2000b). Since the EU made a special trade deal with South Africa, it revised its 2000 duty-free import quota at 515,000 t for South Africa; 520,000 t for all other countries combined. EU left its 2001 duty-free quota for South Africa unchanged while reducing that for all other countries to 400,000 t (Ryan's Notes, 2001c).

Finland.—Outokumpu Polarit Oy planned to merge with Avesta Sheffield (Sweden, United Kingdom). See Sweden section. Outokumpu reported on its ferroalloys production process using preheated charge. Sintered pellets and other charge components are heated before being charged into the smelting furnace (called preheated) on a moving steel belt over which hot gasses from the closed smelting furnace are passed. The system was developed to process chromite ore from Kemi Mine. The process was developed to consume little electrical energy for smelting, have high on-line availability, good working conditions, and adequate environmental aspects (Nurmisalo, 2000). Outokumpu planned the addition of a new melt shop and hot- and cold-rolling facilities that were expected to double output at Tornio works to 800,000 t in 2002.

France.—Delachaux Metals Division produced chromium metal by aluminothermic reduction. Delachaux reported that world demand for chromium metal in 2000 increased to 21,000 t from 20,000 t in 1999. The major end uses for chromium metal were the production of superalloys for use in gas turbine engines or petrochemical production. Delachaux estimated its

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production in 2000 to be 5,500 t (Metal Bulletin Books, 1995, p. 42; TEX Report, 2000g).

Germany.— ThyssenKrupp Group made a purchase guarantee with SA Chrome and Alloys (South Africa), a startup ferrochromium producer. ThyssenKrupp committed to purchase 230,000 t/yr of high-carbon ferrochromium from SA Chrome and Alloys for 5 years.

India.—The Ministry of Commerce conducted a review of the antidumping duty imposed in January 1997 that found no evidence of injury to domestic industry by the import of low-carbon ferrochromium from Kazakhstan or Russia. Ferro Alloys Corp. Ltd., the only domestic low-carbon ferrochromium producer, has not produced the material for the past 2 years (Metal Bulletin, 2000h; Platt's Metals Week, 2000b).

Ferro Alloys Corp. Ltd. resumed production at Garividi and at Shreeram Nagar. The Garividi plant was closed for financial reasons. The Shreeramnagar plant was closed over a labor dispute. Ferro Alloys Corp. Ltd. exported chromite ore for the first time. Ferro Alloys Corp. Ltd. reported annual ferrochromium production of 87,000 t in 1998 and 51,000 t in 1999. (Metal Bulletin, 2000d, n; TEX Report, 2000f).

Indian Metals and Ferroalloys Ltd. started opencast mining in the Sukinda Valley. Indian Metals and Ferroalloys received 190 hectares (ha) containing 21 Mt of chromite ore reserves when the Government redistributed Sukinda Valley resources in 1999. Chromite ore production reached 31,000 t/mo in May, enough to supply its ferroalloy plants. Indian Metals and Ferroalloys used that chromite ore to feed its ferrochromium smelters at Therubali and Choudwar. At Therubali, Indian Metals and Ferroalloys operated three furnaces electrically rated at 48 megavolt-amperes, 24 megavolt-amperes, and 10 megavolt-amperes. The plant's annual ferrochromium production capacity was 110,000 t; however, Indian Metals and Ferroalloys was producing ferrochromium at the rate of 30,000 t/yr from the 24 megavolt-ampere furnace. Indian Charge Chrome Ltd. was producing ferrochromium at the annual rate of 60,000 t from a 48 megavolt-ampere furnace at Choudwar. Indian Metals and Ferroalloys reported annual production of 56,000 t in 1998 and 67,000 t in 1999 (TEX Report, 2000h).

Jindal Strips Ltd., Ferro Alloys Division planned to exploit chromite ore resources allocated to it when the Government redistributed Sukinda Valley resources in 1999. Jindal planned to produce ferrochromium at the annual rate to 60,000 t at its plant in Andhra Pradesh State (TEX Report, 2000k).

Tata Iron and Steel Co. Ltd. reported 1999 ferrochromium production of 100,000 t and planned to increase that in 2000. Tata produced ferrochromium at its Bamnipal plant in India and under agreements with five other domestic companies operating nine furnaces and five Chinese plants operating seven furnaces. Tata reported 1999 chromite ore production of 772,000 t with plans to increase that to 1,000,000 t by exploiting resources assigned to it when the Government redistributed Sukinda Valley resources in 1999; Tata also reported chromite ore concentrate production of 200,000 t with plans to increase that to 300,000 t. To meet ferrochromium expansion goals, Tata bid to buy Industrial Development Corp.'s ferroalloy plant. To reduce electrical energy cost and assure supply, Tata requested permission to build a powerplant in Orissa. Another plan by Tata to increase ferrochromium production while avoiding the high cost of electrical energy was to build a ferrochromium plant in Australia that would use chromite ore mined by Tata in India (see Australia section) (Lobo, 2000; Metal Bulletin, 2000m, n, p; TEX Report, 2000x).

Iran.—Abdan Ferroalloy Refinery produced ferrochromium with an annual capacity of 15,000 t from a 12.5-megavolt-ampere furnace. The company also operated the Ne'Mat chromite ore mine. The mine's annual production capacity was 400,000 t, some of which was processed in its 120,000-t/yr concentrator.

Iran produced chromite ore in excess of its domestic needs. To increase value added exports, the Government planned to increase domestic annual ferrochromium production to 200,000 t by 2005. New production facilities were planned for the provinces Kerman and Fars. Baft Ferrochrome Industrial Company and Nahid Ehyan Sepahan contracted with ABB Engineering Company (Sweden, Switzerland) to build two plants, each with an annual ferrochromium production capacity of 25,000 t, for $74 million. Construction was expected to take 2 years (Iran Daily, 2000; Ryan's Notes, 2000l).

Japan.—Japan imported 501,727 t of chromite ore; 714,531 t of high-carbon, and 61,796 t of low-carbon ferrochromium; and 3,202 t of chromium metal. Japan produced 131,759 t of high- and low-carbon ferrochromium. Stainless steel production was 3.447 Mt. Ferrochromium imports represented 85% of market share. Japan exported 2,541 t of ferrochromium and 1.162 Mt of stainless steel. Japan had stainless steel scrap imports of 211,581 t and exports to 70,676 t (TEX Report, 2001c, f, g, h, i, j, k).

Based on chromite ore, ferrochromium, chromium metal, and stainless steel scrap trade, chromium apparent consumption in Japan was 586,000 t contained chromium. Japan had a duty-free quota for the importation of ferrochromium amounting to 28,100 t in FY 2000. There was a preferential duty of 3.18% and a temporary duty of 5.3% imposed effective April 1, 2001 (April 1, 2000, through March 31, 2001) (TEX Report, 2001m).

The Ministry of International Trade and Industry reported its intent to review the goals of the rare metals stockpile, which included chromium metal, taking into account current political conditions, budget constraints, and rare metal demand. The rare metals stockpiling program has been active since 1984, at which time chromium was identified as one of the rare metals that would be stocked in the amount necessary to meet 60 days of demand (TEX Report, 2000o). A stockpile equivalent to 78.2% of the goal for chromium had been reached. The review found that the amount of chromium held in the stockpile could be reduced. J S Processing Co. Ltd. is a new business setup in Osaka to supply blended scrap to Nippon Steel Corp. The company is a joint venture among ELG Haniel Metals Corp. (40%), Mitsui and Co. Ltd. (19%), Mitsubishi Corp. (19%), Nippon Steel Trading Co. Ltd. (12%), Fujimoto Kinzoku (5%), and Sangyo Shinko (5%). The company anticipated handling 3,000 t/mo of scrap, of which 1,000 t would be blended (TEX Report, 2000i, j).

High-carbon ferrochromium producers and production in Japan in 2000 were: Nippon Denko Co. Ltd., 7,113 t; NKK Materials Co. Ltd., a subsidiary of NKK Corp., 31,948 t; and Shunan Denko K.K., a subsidiary of Showa Denko K.K.,

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83,909 t (TEX Report, 2001c).

NKK Materials Co. Ltd. reported the development of a new product, 99.5% pure chromium metal. NKK Materials implemented its two-step electric furnace refining process followed by vacuum degasification at its Toyama plant. NKK expected the chromium metal to be used by master alloy producers for the aircraft industry, a market sector that NKK currently supplies with low-carbon ferrochromium. NKK planned to produce about 1,000 t/yr, developing its chromium metal production capacity to 3,000 t/yr (Metal Bulletin, 2000i; TEX Report, 2000n).

Japan houses about one-fifth of the world's stainless steel industry with a production capacity well in excess of its domestic demand. That industry has participated in the trend to make strategic alliances between ferrochromium consumers, that is themselves, and ferrochromium producers in South Africa. As no new alliances have originated over the past 2 years, that trend appears to have played out. The stainless steel industry itself is now undergoing changes in Japan. From 1961 through 2000, stainless steel production (excluding heat resisting grades) in Japan has grown from 199,462 t to 3,021,080 t, a compounded growth rate of 7.22%. The major stainless steel-producing companies that also operate blast furnaces, their stainless steel production locations, and production in 2000 were Kawasaki Steel Corp., Chiba, 683,858 t; Nippon Metal Industry, Kinuura, 318,888 t; Nippon Steel, Hikari and Yawata, 1,105,318 t; Nippon Yakin Kogyo Co. Ltd., Kawasaki, 337,840 t; Nisshin Steel Co., Shunan, 629,072 t; and Sumitomo Metal Mining Co. Ltd., Wakayama and Naoetsu, 551,672 t. Nippon Steel and Sumitomo agreed to specialize. Nippon Steel was to specialize in producing stainless steel coils; Sumitomo in pipes and shaped steels. Nippon Steel also reached an agreement with Nisshin Steel wherein Nippon Steel would specialize in austenitic (that is, chromium-nickel-containing) grades and Nisshin would specialize in ferritic (that is, chromium-containing) grades. By these agreements, each company expected to benefit economically by producing larger volumes of fewer products and permitting the elimination of excess production capacity (TEX Report, 2000e, 2001d, e). Japan has exported a substantial fraction of its stainless steel production. In recent years, stainless steel production capacity has been developed in Asia, namely in the Republic of Korea and Taiwan. Since new capacity has come into production faster than demand expansion, adjustments are necessary. Capacity reduction takes place where production is least efficient; that is, in older facilities. The older facilities in Asia are in Japan.

Kazakhstan.—Kazchrome was co-owned by Trans World (Alloys) Inc. and the Government of Kazakhstan. A dispute arose in 1997 between Trans World and local company officials over who would control and manage the mine and ferrochromium smelters. The dispute was settled in 2000 when the Chodiev Group (also known as Kazakhstan Mineral Resource Corp.) bought Trans World's interest in the Kazchrome. Kazchrome owns the Donskoy Ore Dressing Complex and the Aksusky Ferroalloy Plant (Aksu) and Aktyubinsk Ferroalloy Plant. Kazchrome was owned by Kazakhstan Mineral Resource Corp. (28.75%), the Kazakhstani Government (31.3%), and holds its own stock (28.75%).

Kazakhstan's chromium industry includes Donskoy Ore Dressing Complex, Aksu, and Aktyubinsk Ferroalloy Plant. Donskoy extracted chromite ore from the Poiskovy open pit and the Molodyonzhnaya underground mines (TEX Report, 2000m). Donskoy completed construction of equipment that will produce briquettes from chromite ore fines, with an annual capacity of 500,000 t (TEX Report, 2001l). Aksu installed a new 64-megavolt-ampere furnace manufactured by Mannesmann-Demag (Germany) that has a high-carbon ferrochromium production capacity of 102,000 t/yr. Aksu planned to add about 160,000 t of high-carbon ferrochromium production capacity in the form of two 50-megavolt-ampere or three 30-megavolt-ampere furnaces in 2002 (Ryan's Notes, 2000e; TEX Report, 2000l).

Norway.—Elkem ASA produced high-carbon ferrochromium containing 60% to 65% chromium from two closed furnaces at its ferrochromium plant in Rana. Annual production capacity was 160,000 t (Ryan's Notes, 2000h).

Philippines.—The four ferrochromium producers in the Philippines were reported to have ceased production several years ago (Bennet, Barrand, and Clarkson, 2000). Benguet Corporation mined foundry and refractory grades of chromite ore at Masinloc Chromite Operation in Zambales Province. Having developed a stockpile equivalent to 15 to 18 months of consumption, Benguet temporarily suspended production in 1999 to reduce stocks (Industrial Minerals, 1999). Having depleted its stockpile, Benguet started underground chromite ore mine production (Platt's Metals Week, 2000a).

Russia.—Serov Ferroalloy Plant reported production of 129,500 t of ferrochromium in 1999: 90,000 t of high-carbon ferrochromium; 18,500 t of medium-carbon ferrochromium; and 21,000 t of low-carbon ferrochromium. The plant is 359 km from Sverdlovsk. It uses locally mined and imported chromite ore. Serov was developing a new mine at Salechard, which it expected to yield chromite ore of higher grade than that currently available from local sources. Serov imported ore from Kazakhstan and Turkey (Metal Bulletin, 2000k).

Severonickel Combine, a subsidiary of RAO Norilsk Nickel, continued development of the Sopcheozero chromite deposits. Norilsk sought a partner to develop the chromite ore mine and a ferrochromium smelter (Ryan's Notes, 2000b).

Chelyabinsk Electrometallurgical Integrated Plant produced low-carbon ferrochromium with an annual production capacity of 144,000 t. Chelyabinsk imported its chromite ore from Kazakhstan (Ryan's Notes, 2001a). Chelyabinsk planned to install a scrap recycling circuit (Ryan's Notes, 2000g).

South Africa.—The Minerals Bureau reported that, from a reserve base of 3,100 Mt of chromite ore, in 1999 South Africa produced 6,817,000 t of chromite ore from which it produced 2,155,000 t of ferrochromium and other products. South Africa exported 841,000 t of chromite ore and 1,897,100 t of ferrochromium in 1999 (Armitage, 2000). Based on chromite ore production and chromite ore and ferrochromium trade, 1999 South African chromium apparent consumption was 755,658 t, contained chromium. The Minerals Bureau reported chromite ore production in 2000 of 6,620,754 t and sales of 6,744,278 t. Eighty-five percent of sales was sold locally; the remaining 15% was exported (South African Minerals Bureau, 2001).

South Africa considered changing its mining law. Currently,

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companies own mineral property rights. Draft legislation would change to government ownership of minerals and government licensing of mining for a specified period of time (Ryan's Notes, 2000h, k). Eskom, the South African power company, planned to change its billing structure for the ferrochromium industry, as their current 7-year contract with that industry comes to a close. The current contract adjusts the price of electrical energy between minimum and maximum rates based on the price of ferrochromium. The proposed system would be a fixed tariff rate of 12.2 cents per kilowatthour. Eskom was the fifth largest electrical power producer worldwide and planned to be privatized (Metal Bulletin, 2000l; Ryan's Notes, 2000f, 2001d). South African environmentalists made their desire for stricter pollution-control standards known at public hearings held to discuss the environmental impact of new plants or new furnaces (Ryan's Notes, 2000m).

ASA Metals (Pty.) Ltd. planned another furnace and an agglomeration facility for its ferrochromium plant near Burgersfort, Northern Province. ASA completed construction and started production at its ferrochromium plant last year. ASA had an annual ferrochromium production capacity of 60,000 t from a 33 megavolt-ampere furnace. ASA is a joint venture between Northern Province Development Corporation (40%) and East Asian Metals Investment Co. Ltd. (60%) (Lourens, 2000).

South Africa Chrome and Alloys Ltd. (SAChrome), formerly Southern Witwatersrand Exploration Co., studied the feasibility of constructing a ferrochromium plant. The plant was to use chromite ore from its Horizon and Chromeden mines. SAChrome planned to build a pelletizing and sintering plant with an annual capacity of 520,000 t and a ferrochromium plant with annual production capacity of 230,000 t. They planned two closed furnaces with electrical capacity of 54 megavolt-amperes each. The plant was to be located near Boshoek at a rail siding about 40 km from the mine and about 650 km from Richards Bay. Plant cost was estimated at about $100 million. SAChrome planned to use chromite ore from the UG-2 and LG-6 seams to produce ferrochromium containing 51% chromium. Thyssen Krupp Metallurgie contracted to take up to 250,000 t/yr of ferrochromium for 5 years from SAChrome (Graulich, 2000; Ryan's Notes, 2000d, m, 2001b).

Associated Manganese Mines of South Africa Ltd. (Assmang) started production at the Dwarsrivier chromite ore mine in Mpumalanga Province about 30 km from Steelpoort (Mining Journal, 2000b). The opencast mine and beneficiation plant located at the mine site had an annual production capacity of about 350,000 t/yr. Assmang planned to start underground mining in 2001, thereby bringing production capacity up to about 1 million tons per year. The LG-6 seam, which dips at 8 degrees to 14 degrees and has a thickness of about 180 centimeters, was being mined. Within the mine, ore was transported by conveyor belt from the pit to the beneficiation plant. From the plant, ore was trucked to the Steelpoort rail terminal from which it was carried by train the remaining 60 to 65 km to Feralloys, Assmang's ferrochromium plant at Machadodorp (http://www.avmin.co.za/mediashop/pressreleast.asp?story=5, downloaded April 13, 2000) (TEX Report, 2000a). Feralloys operated three furnaces and a metal-from-slag recovery process. The furnaces accounted for an annual ferrochromium production capacity of about 125,000 t; the metal-from-slag recovery was 25,000 t. Two of their three furnaces had electrical capacity of 24 megavolt-amperes; the third furnace, 30 megavolt-amperes. The two 24-megavolt-ampere furnaces were upgraded to 30 megavolt-amperes, bringing Feralloys' ferrochromium production capacity up to 175,000 t/yr (Metal Bulletin, 2000g). A fourth furnace and pelletizing plant of Outokumpu technology was planned. The fourth furnace was planned to have an electrical capacity of 54 megavolt-amperes and ferrochromium production capacity of 130,000 t/yr. The pelletizing plant was planned to produce 350,000 t/yr of pellets (Metal Bulletin, 2000f).

Columbus Stainless Steel estimated its production of stainless steel flat products to have been 440,000 t in 2000, of which 105,000 t was sold domestically (Metal Bulletin, 2000c).

Hernic (Pty.) Ltd. brought its third furnace into production. The third furnace is supported by pelletizing and preheating operations manufactured by Outokumpu Oy (Finland). The system was installed at a cost of about 200 million Rand and increased Hernic's annual ferrochromium production capacity to 260,000 t (Venter, 2000b).

Samancor Ltd. planned a greenfield ferrochromium plant in the western belt of the Bushveld Complex near its Mooinooi Mine. Samancor planned to construct two closed furnaces to be fed by one pelletizing and sintering plant on a 50-ha site at a cost of 500 million Rand. Production technology is from Outokumpu Technology (Finland) that Samancor is using at its Ferrometals plant. This will be Samancor's first ferrochromium plant in the western belt of the Bushveld complex. The mine was expected to produce about 760,000 t/yr of chromite ore. The smelter was expected to produce 520,000 t/yr of preheated pellets, from which about 300,000 t/yr of ferrochromium would be produced. The plans were reported to have included the use of UG-2 chromite byproduct from platinum mining and iron and steel scrap (Venter, 2000a). Samancor anticipated proceeding with plant construction when market conditions indicated the need for this new plant (Gonsalves, 2000).

Xstrata S.A. (Pty.) Ltd. was developing the Townlans Mine in the Rustenburg area, western belt of Bushveld Complex. The mine was expected to start production in 2001 and have a production capacity of 480,000 t/yr. The new mine complements Xstrata's existing mines in the western belt: Waterval, 273,000 t/yr production capacity and Kroondal Mine, 663,000 t/yr; and the Thorncliffe Mine, 1,056,000 t/yr in the eastern belt (TEX Report, 2000y).

Samancor and Xstrata formed an equally owned joint venture to develop chromite ore mining and ferrochromium production in the Rustenburg area of the western belt of the Bushveld Complex. The joint venture will develop chromite ore reserves owned by Samancor that are accessable via Xstrata's Kroondal Mine and will expand Xstrata's Wonderkop smelter. The Wonderkop smelter near Rustenburg had an annual ferrochromium production capacity of about 300,000 t from four, 39 megavolt-ampere furnaces, two pelletizing lines, and a recovery plant. Wonderkop obtained its chromite ore supply primarily from the Kroondal Mine. Samancor and Xstrata planned to add two 45 megavolt-ampere furnaces, pelletizing and prereduction, and metal-from-slag recovery at a cost of

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about $40 million. The new production equipment will add 180,000 t/yr of ferrochromium to the plant's annual production capacity. Additional chromite ore supplies will come through development of the Kroondal Mine to exploit reserves owned by Samancor. Production was expected to start in 2001 (Metal Bulletin, 2000j; Mining Journal, 2000a; Platt's Metals Week, 2000c; Robinson, 2000b; Ryan's Notes, 2000i; TEX Report, 2000p).

Sweden.—Vargön Alloys AB planned to purchase a recovery plant that would recover ferrochromium from slag. The plant was planned to process slag at the rate of 100 metric tons per hour. The equipment supplier was Apic Toll Treatment, a joint venture between Mintek and Bateman Titaco Company (Robinson, 2000a).

The European stainless steel producers Avesta Sheffield Ltd. (Sweden, United Kingdom) and Outokumpu Polarit Oy (Finland) merged to form AvestaPolarit Abp. Avesta Sheffield is the result of the merger of Avesta (Sweden) and British Stainless Steel (UK) in 1992. The merger was to be effected in 2001. The new company would have a stainless steel production capacity of 1.7 Mt. Other stainless steel producers in Europe include Acciai Speciali Terni SpA (Italy), Acerinox SA (Spain), ALZ NV (Belgium), Ugine SA (France), and Krupp-Thyssen Nirosta GmbH (Germany). Raw materials supply appears to favor Outokumpu Polarit's plant at Tornio because it is near to chromium and nickel supply (Metal Bulletin Books, 1995, p. 4, 18, 30, 48, 79, 96; Avesta Sheffield, 2000; TEX Report, 2000q).

Taiwan.—Taiwan reported production of ferrochromium to have been 296,297 t high carbon in 1998; 387,995 t high carbon in 1999; and 380,996 t high carbon, and 14,175 t low carbon in 2000 (TEX Report, 2001n, o). Taiwan reported stainless steel scrap imports of 20,789 t in 2000 (TEX Report, 2000v). Taiwan reported stainless steel scrap exports of 45,095 t in 1998 and 49,055 t in 1999 (TEX Report, 2000u).

Tang Eng Iron Works, Yieh United Steel, Walsin Carteck, and China Steel Corp. produced about 1.2 Mt of stainless steel in 2000 (TEX Report, 2000w).

Turkey.—Eskikaya and Aydiner (Eskikaya and Aydiner, 2000) reported that Turk Maadin A.S. operated the Dagardi, Kavak, Koycegiz, and Tavas chromite ore mines. The Kavak Mine had 2 Mt of reserves, and annual production was about 100,000 t. Eskikaya reported that mine performance was improved when they introduced new mining techniques and equipment. In particular, the improvements reduced accidents, manpower required, and timber consumption. These savings could extend the reserves and mine life by making low-grade ore production economical.

Zimbabwe.—Zimbabwe Alloys Ltd. reported production of 33,425 t of low-carbon ferrochromium in 1999. Zimbabwe Alloys renovated its Gweru plant. It converted one 28-megavolt-ampere furnace from the production of ferrochromium-silicon to the production of high-carbon ferrochromium. The conversion cost about $3 million. The new furnace had a high-carbon ferrochromium production capacity of 35,000 t/yr. Zimbabwe Alloys will continue to produce low-carbon ferrochromium under a joint-venture agreement with Japan Metals and Chemicals Co. (Japan) (Ryan's Notes, 2000n).

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Mintek found that dry milling of ferrochromium slag or chromite ore produces a buildup of chromium in the +6 valence state. Chromium in chromite ore is in the +3 valence state. Mintek found that longer duration milling resulted in higher concentration of chromium in the +6 valence state (Mintek Bulletin, 2000).

Outlook

The outlook for chromium consumption in the United States and the rest of the world is about the same as that for stainless steel, which is the major end use for chromium worldwide. Thus, stainless steel industry performance largely determines chromium industry demand worldwide. (See the following section on stainless steel.)

Several trends are occurring simultaneously in the chromium industry. Chromite ore production is moving from independent producers to vertically integrated producers. In other words, chromite ore mines tend to be owned and operated by ferrochromium or chromium chemical producers. This trend is associated with the migration of ferrochromium production capacity from stainless steel-producing countries to chromite ore-producing countries. As ferrochromium-production capacity is rationalized in historically producing countries, which are usually stainless steel producing countries, new furnaces or plants are constructed in chromite ore producing areas. The electrical power capacity and production capacity of submerged-arc electric furnaces used to produce ferrochromium has been increasing. Production process improvements such as agglomeration of chromite ore, preheating and prereduction of furnace feed, and closed furnace technology have been retrofitted at major producer plants and are being incorporated into newly constructed plants. When ferrochromium plants started to be built, furnaces rated in the low kilovoltampere range were common. Furnaces built recently tend to approach the mid megavolt-ampere range. The introduction of post melting refining processes in the steel industry after 1960 started a shift in consumption from low-carbon ferrochromium to high-carbon ferrochromium causing a decline in low-carbon ferrochromium production that continues today. After years of ferrochromium production, slag stockpiles have built up. Recently developed processes efficiently recover ferrochromium from that slag. Equipment to use these processes was being installed at plant sites. In South Africa, the major chromite ore- and ferrochromium-producing country, two trends are emerging; ferrochromium plants are being developed in the western belt of the Bushveld Complex, and chromite ore byproduct from platinum operations are being accommodated by new production processes. After many years of stainless steel production, stainless steel scrap resources have accumulated. Stainless steel producers have been improving their production processes by reducing scrap generated during the production process and by increasing the amount of scrap used as feed material. As a result, the fraction of stainless steel scrap use as feed material has been increasing, especially from post consumer sources.

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References Cited

Armitage, W.K., 2000, Chromium *in* South Africa's Minerals Industry 1999-2000 (17th ed.): Republic of South Africa, Department of Minerals and Energy, January 2001, p. 104-109.

Avesta Sheffield, 2000, Outokumpu and Avesta Sheffield form new leading stainless steel company: Avesta Sheffield press release, September 28, 19 p.

Bennet, Amy, Barrand, Tom, and Clarkson, Dan, 2000, A strategic analysis of the global ferro-chrome industry: United Kingdom, Metal Bulletin Research, December, 88 p.

Cesar, José Rafael de Andrade, 2000, Chrome: Mineral Summary 2000, v. 20, p. 33-34.

Eskikaya, Sinasi, and Aydiner, Selahattin, 2000, Expectations and realization-full achievement of the objectives in terms of profitability and safety in Kavak chrome mine: Las Vegas, NV, Presentation at Mine Expo 2000, September 2000, 17 p. handout.

Gonsalves, Marc, 2000, Closure of two furnaces at Ferrometals: Samancor Chrome press release, August 24, 3 p.

Graulich, Ilja, 2000, SA Chrome pins hopes on smelter: Business Day, November 24, p. 27.

Industrial Minerals, 1999, Benguet suspends chromite output: Industrial Minerals, no. 376, January, p. 15-16.

Iran Daily, 2000, $74 million ferrochrome deal: Iran Daily, June 18, p. 3.

Lobo, Gilbert, 2000, Tata's plans to grow in chrome: Metal Bulletin Monthly, no. 359, November, p. 19, 21.

Lourens, Carli, 2000, Chinese commission chrome smelter: Mining Weekly, January 28–February 3, p. 23.

Metal Bulletin, 2000a, Eurofer welcomes new ferro-chrome quota: Metal Bulletin, no. 8441, January 13, p. 7.

———2000b, European Commission lifting of anti-dumping duties will 'create world price': Metal Bulletin, no. 8463, March 30, p. 8.

———2000c, Expansion yields profit for Columbus: Metal Bulletin, no. 8481, June 5, p. 17.

———2000d, Facor to export chrome ore: Metal Bulletin, no. 8484, June 15, p. 12.

———2000e, Facor to reopen Garividi plant: Metal Bulletin, no. 8483, June 12, p. 7.

———2000f, Feralloys signs FeCr plant deal: Metal Bulletin, no. 8489, July 3, p. 9.

———2000g, Good progress made at Assmang expansions: Metal Bulletin, no. 8455, March 2, p. 8.

———2000h, India to remove anti-dumping duty on ferro-chrome imports: Metal Bulletin, no. 8525, November 13, p. 10.

———2000i, Japanese producer ships samples of Fe Cr metal output: Metal Bulletin, no. 8504, August 31, p. 7.

———2000j, Samancor and Xstrata agree production joint venture: Metal Bulletin, no. 8483, June 12, p. 6.

———2000k, Serov looks to boost FeCr exports to Asia: Metal Bulletin, no. 8468, April 17, p. 11.

———2000l, South African FeCr costs set to rise: Metal Bulletin, no. 8529, November 27, p. 8.

———2000m, Tisco bids to take over Orissa Fe-Cr plant: Metal Bulletin, no. 8501, August 17, p. 9.

———2000n, Tisco looks to export chromite ore to customers: Metal Bulletin, no. 8479, May 29, p. 15.

———2000o, Tisco plans FeCr plant in Australia: Metal Bulletin, no. 8534, December 14, p. 8.

———2000p, Tisco revised FeCr production estimate: Metal Bulletin, no. 8506, September 7, p. 15.

———2001, Ferro-chrome plant to be built in Gladstone: Metal Bulletin, no. 8540, January 11, p. 9.

Metal Bulletin Books, 1995, Stainless Steel Databook (3d ed.): England, Metal Bulletin Books Ltd., 514 p.

———1998, Ferro-Alloy Directory and Databook (5th ed.): England, Metal Bulletin Books Ltd., 418 p.

Mining Journal, 2000a, Chrome rivals pool assets: Mining Journal, v. 334, no. 8586, June 9, p. 450.

———2000b, Dwarsrivier mine opened: Mining Journal, v. 335, no. 8606, October 27, p. 339.

Mining Weekly, 2000, Gauteng improves Brazilian operation: Mining Weekly, June 16-22, p. 16.

Mintek Bulletin, 2000, Generation fo Cr (VI): Mintek Bulletin, no. 130, December 2000-January 2001, p. 2.

Nurmisalo, Martti, 2000, Ferroalloys production with preheated charge: Beijing, presentation at International Ferroalloys Fair 2000, October 23-26, 10 p.

Platt's Metals Week, 2000a, Benguet resumes chrome ore mining: Platt's Metals Week, v. 71, no. 19, May 8, p. 9.

———2000b, India lifts duty on low-C chrome: Platt's Metals Week, v. 71, no. 48, November 27, p. 10.

———2000c, Samancor, Xstrata in chrome JV: Platt's Metals Week, v. 71, no. 24, June 12, p. 3.

Resource Information Unit, 2000, Chromium: Register of Australian Mining 2000-2001, 672 p.

Robinson, Ian, 2000a, Contract for alloy from slag plant awarded: SA Mining, Coal, Gold and Base Minerals, January 2001, p. 17.

———2000b, South African producers look to the long-term: Metal Bulletin Monthly/Ferro-Alloys Supplement, no. 359, November, p. 14-17.

Ryan's Notes, 2000a, ELG to control 500,000 mt of Cr units: Ryan's Notes, v. 6, no. 15, April 10, p. 15.

———2000b, Etibank offers low Cr FeCr: Ryan's Notes, v. 6, no. 38, September 18, p. 2.

———2000c, European charge chrome talks begin: Ryan's Notes, v. 6, no. 26, June 26, p. 3.

———2000d, European mills to pay 2-3¢ more for charge chrome in second quarter: Ryan's Notes, v. 6, no. 12, March 20, p. 1-2.

———2000e, FeCr producers looking ahead: Ryan's Notes, v. 6, no. 48, November 27, p. 2.

———2000f, FeCr under producers dominance: Ryan's Notes, v. 6, no. 40, October 2, p. 1-2.

———2000g, Greens make their voice heard on chrome: Ryan's Notes, v. 6, no. 22, May 29, p. 1-2.

———2000h, Large tenders dominate FeCr market: Ryan's Notes, v. 6, no. 52, December 25, p. 1.

———2000i, Samancor and Xstrata in new joint venture: Ryan's Notes, v. 6, no. 34, June 12, p. 1.

———2000j, Second quarter FeCr buying begins: Ryan's Notes, v. 6, no. 9, February 28, p. 3.

———2000k, Uneasy quiet in ferrochrome: Ryan's Notes, v. 6, no. 46, November 13, p. 1-2.

———2000l, US low carbon FeCr prices fall: Ryan's Notes, v. 6, no. 25, June 19, p. 3.

———2000m, US low-carbon FeCr prices sink: Ryan's Notes, v. 6, no. 39, September 25, p. 1-2.

———2000n, Zimalloys to produce HC FeCr: Ryan's Notes, v. 6, no. 11, March 13, p. 1.

———2001a, Chelyabinsk halves low C FeCr output: Ryan's Notes, v. 7, no. 2, January 1, p. 1-2.

———2001b, Etibank restructures its Cr operations: Ryan's Notes, v. 7, no. 2, January 8, p. 1.

———2001c, Samancor dramatically trims FeCr output: Ryan's Notes, v. 7, no. 3, January 15, p. 1.

———2001d, Xstrata studying further chrome cutbacks: Ryan's Notes, v. 7, no. 5, January 29, p. 2.

South African Minerals Bureau Report, 2001, ME-P-014: May 2, unpaginated.

Syracuse Research Corp., 2000, Toxicological profile for chromium (update), 2000: Syracuse, NY, Syracuse Research Corp., September, 435 p.

TEX Report, 2000a, Assmang/S. Africa participates in expansion of chrome operations: TEX Report, v. 32, no. 7572, June 13, p. 2-3.

———2000b, China's exports of ferro-alloys in 1999 increased slightly compared to 1998: TEX Report, v. 32, no. 7613, August 10, p. 6-7.

———2000c, China's imports of Cr-Ore in 1999 increased by 15%: TEX Report, v. 32, no. 7621, August 23, p. 6.

———2000d, China's policy to rectify structure of ferro-alloy industry is gradually permeating: TEX Report, v. 32, no. 7654, October 11, p. 4-5.

———2000e, Cr-based stainless steel production is being concentrated on Kawasaki Steel and Nippon Steel: TEX Report, v. 32, no. 7555, May 19, p. 8-9.

———2000f, FACOR/India resumed to operate Sheeramnagar plant in last week: TEX Report, v. 32, no. 7582, June 27, p. 1.

———2000g, Favorable world demand for Cr-met in this year is estimated at 21,000 tons: TEX Report, v. 32, no. 7682, November 21, p. 1.

———2000h, IMFA Group/India launches to develop chrome resources in Sukinda Valley: TEX Report, v. 32, no. 7584, June 29, p. 4.

———2000i, Japan—USA joint venture company is established for S/S blended scrap commenced its operations: TEX Report, v. 32, no. 7582, June 27, p. 6.

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———2000j, Japan—USA joint venture company is established for S/S blended scrap to Nippon Steel: TEX Report, v. 32, no. 7500, February 28, p. 4-5.
———2000k, Jindal/India plans to export 16,000 tons/year of Fe-Cr: TEX Report, v. 32, no. 7652, October 6, p. 6.
———2000l, Kazakhstan expands capacity for HC-Fe-Cr to produce 880,000 tons in 2002: TEX Report, v. 32, no. 7567, June 6, p. 2.
———2000m, Kazakhstan's plans to produce ferro-alloys in 2000: TEX Report, v. 32, no. 7506, March 7, p. 2.
———2000n, NKK Material launches to produce high grade Cr-met: TEX Report, v. 32, no. 7622, August 24, p. 6.
———2000o, Review of rare metals stockpile may put slight impact on industries concerned: TEX Report, v. 32, no. 7598, June 19, p. 6.
———2000p, Samancor and Xstrata enter into Fe-Cr joint venture: TEX Report, v. 32, no. 7572, June 13, p. 6.
———2000q, Stainless steel industry in Europe is coming at opportune time to reorganize again: TEX Report, v. 32, no. 7650, October 4, p. 6-7.
———2000r, Supply/demand of ferro-alloys in Brazil for 1999(1): TEX Report, v. 32, no. 7659, October 18, p. 7.
———2000s, Supply/demand of ferro-alloys in Brazil for 1999(3): TEX Report, v. 32, no. 7661, October 20, p. 7.
———2000t, Supply/demand of ferro-alloys in Brazil for 1999(4): TEX Report, v. 32, no. 7662, October 23, p. 6.
———2000u, Taiwan's exports of stainless steel scrap in December 1999: TEX Report, v. 32, no. 7519, March 27, p. 5.
———2000v, Taiwan's imports of HC-Fe-Cr in December 1999: TEX Report, v. 32, no. 7519, March 27, p. 3.
———2000w, Tang Eng Iron Works/Taiwan holds tender to purchase 32,000 tons Fe-Cr: TEX Report, v. 32, no. 7700, December 18, p. 8.
———2000x, TISCO/India plans to expand its chrome operations: TEX Report, v. 32, no. 7565, June 2, p. 1.
———2000y, Xstrata/S.Africa expands its capacity to comply with increasing SUS production: TEX Report, v. 32, no. 7562, May 30, p. 2.
———2001a, China's exports of ferro-chrome in 2000: TEX Report, v. 33, no. 7746, March 1, p. 6.
———2001b, China's imports of Cr-Ore in by source in 2000: TEX Report, v. 33, no. 7749, March 6, p. 5.
———2001c, Domestic output and imports of ferro-alloys in Japan for year 2000: TEX Report, v. 33, no. 7762, March 26, p. 8.
———2001d, General review of stainless steel in 2000 and its outlook for a new year (1): TEX Report, v. 33, no. 7748, March 5, p. 2-3.
———2001e, General review of stainless steel in 2000 and its outlook for a new year (2): TEX Report, v. 33, no. 7749, March 6, p. 4.
———2001f, (Custom Statistics) Japan's exports of ferro-alloys in December 2000: TEX Report, v. 33, no. 7743, February 26, p. 7.
———2001g, Japan's exports of stainless steel products in year 2000 decreased by 3%: TEX Report, v. 33, no. 7745, February 28, p. 5.
———2001h, (Custom Statistics) Japan's Imports of ferro-alloys in December 2000: TEX Report, v. 33, no. 7739, February 20, p. 7-8.
———2001i, (Custom Statistics) Japan's imports of raw materials ores (for ferro-alloys production) in December 2000: TEX Report, v. 33, no. 7742, February 23, p. 6-7.
———2001j, Japan's output of stainless steel in year 2000: TEX Report, v. 33, no. 7736, February 15, p. 8-9.
———2001k, Japan's trade of S/S scrap in 2000 was still excess of its imports: TEX Report, v. 33, no. 7751, March 8, p. 10.
———2001l, Kazakhstan's high carbon Fe-Cr is permeating into market with its high quality: TEX Report, v. 33, no. 7754, March 13, p. 4-5.
———2001m, Quota of preferential duty for ferro-alloys and nickel in 2001 fiscal year: TEX Report, v. 33, no. 7770, April 5, p. 3.
———2001n, Taiwan's imports of main ferro-alloys in year 2000: TEX Report, v. 33, no. 7772, April 9, p. 5.
———2001o, Taiwan's raw materials imports in December 2000: TEX Report, v. 33, no. 7776, April 13, p. 7.
U.S. Department of Defense, 2001, Strategic and critical materials report to Congress - Operations under the strategic and critical materials stock piling act during the period October 1999, through September 2000: U.S. Department of Defense, January, 54 p.
Venter, Irma, 2000a, Chrome producer increases production to 800 000 t/yr: Mining Weekly, February 18-24, p. 10.
———2000b, Third furnace at 100% and fourth one being considered: Mining Weekly, February 18-24, p. 6.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Chromium. Ch. in Mineral Commodity Summaries, annual.
Chromium. Ch. in Minerals Yearbook, annual.
Chromium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Chromium. International Strategic Minerals Inventory Summary Report, Circular 930-B, 1984.
Chromium. Mineral Industry Surveys, monthly.

Other

American Iron and Steel Institute.
American Metal Market.
Chromite. Ch. in Industrial Rocks and Minerals, 6th ed., Society for Mining, Metallurgy, and Exploration, Inc., 1994.
Chromium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
CRU Metal Monitor.
The Economics of Chromium (Roskill Information Services, London).
Ferro-Alloy Directory and Databook (Metal Bulletin, London).
Ferro Alloys Manual (The TEX Report, Tokyo).
Ferrous Mineral Commodities Produced in the Republic of South Africa (South African Department of Mineral and Energy Affairs Directory D8).
International Chromium Development Association (Paris).
South Africa's Minerals Industry (Minerals Bureau, South Africa).
Stainless Steel Databook (Metal Bulletin Books, London).

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TABLE 1
SALIENT CHROMIUM STATISTICS 1/

(Metric tons, contained chromium, unless otherwise specified)

	1996	1997	1998	1999	2000
World production:					
Chromite ore (mine) 2/	3,480,000	4,130,000 r/	4,040,000 r/	4,250,000 r/	4,320,000 e/
Ferrochromium (smelter) 3/	2,250,000	2,760,000	2,710,000 r/	2,810,000 r/	2,930,000 e/
Stainless steel 4/	2,750,000	2,960,000	2,920,000	2,940,000	3,110,000 e/
U.S. supply:					
Components of U.S. supply:					
Domestic mines	--	--	--	--	--
Secondary	98,400	120,000	104,000	118,000	139,000
Imports:					
Chromite ore	79,200	96,600	117,000	85,000	86,200
Chromium chemicals	7,060	6,430	9,070	10,400	12,500
Chromium ferroalloys	267,000	237,000	249,000	371,000	344,000
Chromium metal	8,730	9,800	9,520	9,030	9,940
Stocks, January 1:					
Government	1,120,000	1,070,000	1,020,000	928,000	909,000
Industry 5/	80,200 r/	73,800 r/	63,600 r/	59,300 r/	14,000
Total	1,660,000	1,610,000	1,570,000 r/	1,580,000	1,520,000
Distribution of U.S. supply:					
Exports:					
Chromite ore	21,900	5,890	39,900	37,200	44,600
Chromium chemicals	18,200	16,700	17,500	17,300	16,400
Chromium ferroalloys and metal	10,800	7,710	5,000	5,790	25,400
Stocks, December 31:					
Government	1,070,000	1,020,000	928,000	909,000	825,000
Industry 5/	73,800 r/	70,900 r/	59,300 r/	54,000 r/	15,200
Total	1,190,000	1,120,000	1,050,000	1,020,000	926,000
Apparent consumption	468,000 r/	489,000 r/	524,000 r/	558,000	589,000
Reported production: 6/					
Chromium ferroalloy and metal net production:					
Gross weight	36,800	60,700	W	W	W
Chromium content	26,400	40,900	W	W	W
Net shipments	38,800	56,300	W	W	W
Reported consumption:					
Chromite ore and concentrates (gross weight)	282,000	350,000	269,000	W	W
Chromite ore average Cr_2O_3 (percentage)	45	45	45	45	45
Chromium ferroalloys (gross weight)	329,000	385,000	332,000	385,000 r/	354,000
Chromium ferroalloys (contained chromium)	186,000	220,000	187,000	212,000	201,000
Chromium metal (gross weight)	4,500 r/	4,970	4,670 r/	4,690	4,980
Stocks, December 31 (gross weight):					
Government:					
Chromite ore	1,190,000	1,090,000	885,000	820,000	636,000
Chromium ferroalloys	1,050,000	1,020,000	974,000	973,000	919,000
Chromium metal	7,720	7,720	7,720	7,720	7,550
Industry, producer	6,450	10,900	W	W	W
Industry, consumer:					
Chromite ore	173,000	175,000	159,000	130,000	W
Chromium ferroalloys	27,400	16,700	17,300	25,000 r/	26,300
Chromium metal	211 r/	227	195 r/	245	191
Prices, average annual:					
Chromite ore, per ton gross weight 7/	$75	$73	$68	$63	NA
Ferrochromium, per pound chromium content 8/	$0.510	$0.480	$0.467	$0.366	$0.414
Standard chromium metal, per pound gross weight 9/	$4.75	$5.20	$4.73	$4.43	$4.43
Vacuum chromium metal, per pound gross weight 9/	$5.27	$5.39	$5.38	$5.38	$5.42
Value of trade: 10/					
Exports thousands	$111,000	$107,000	$102,000	$92,500	$110,000
Imports do.	$463,000	$450,000	$421,000	$420,000	$427,000
Net exports 11/ do.	($352,000)	($343,000)	($319,000)	($327,000)	($317,000)
Stainless steel (gross weight):					
Production 12/	1,870,000	2,160,000	2,010,000	2,190,000	2,190,000
Shipments 13/	1,730,000	1,880,000	1,850,000	1,890,000	1,930,000
Exports	162,000	199,000	206,000	216,000	264,000
Imports	781,000	774,000	862,000	941,000	989,000

See footnotes the at end of table.

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TABLE 1--Continued
SALIENT CHROMIUM STATISTICS 1/

(Metric tons, contained chromium, unless otherwise specified)

		1996	1997	1998	1999	2000
Stainless steel (gross weight)--Continued:						
Scrap:						
Receipts		579,000	705,000 r/	610,000 r/	694,000 r/	817,000
Consumption		1,040,000	1,140,000	1,040,000	1,140,000	1,220,000
Exports		303,000	370,000	298,000	260,000	468,000
Imports		50,500	64,100	57,200	66,100	56,200
Value of trade:						
Exports	thousands	$583,000	$653,000	$622,000	$628,000	$782,000
Imports	do.	$1,880,000	$1,720,000	$1,680,000	$1,560,000	$2,010,000
Scrap exports	do.	$234,000	$231,000	$176,000	$151,000	$310,000
Scrap imports	do.	$28,500	$33,700	$21,600	$27,700	$35,500
Net exports 11/ 14/	do.	($1,090,000)	($870,000)	($903,000)	($811,000)	($955,000)

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Calculated assuming chromite ore to average 44% Cr_2O_3, which is 68.42% chromium.
3/ Calculated assuming chromium content of ferrochromium to average 57%.
4/ Calculated assuming chromium content of stainless steel to average 17%.
5/ Industry stocks include chromium ferroalloy and metal producer stocks before 1998; and chromite ore consumer stocks before 2000.
6/ Includes chromium ferroalloys and metal and other chromium materials in the United States.
7/ Time-weighted average price of South African chromite ore, as reported in Platt's Metals Week.
8/ Time-weighted average price of imported high-carbon chromium that contains 50% to 55% chromium, as reported in Platt's Metals Week.
9/ Time-weighted average price of electrolytic chromium metal, as reported in American Metal Market.
10/ Includes chromite ore and chromium ferroalloys, metal, and chemicals.
11/ Data indicate that imports are greater than exports.
12/ Data on stainless steel production from American Iron and Steel Institute Annual Reports and quarterly production of stainless and heat-resisting raw steel.
13/ Data on stainless steel shipments from American Iron and Steel Institute Annual Reports.
14/ Includes stainless steel and stainless steel scrap.

TABLE 2
PRINCIPAL U.S. PRODUCERS OF CHROMIUM PRODUCTS IN 2000, BY INDUSTRY

Industry and company	Plant
Metallurgical:	
Eramet Marietta Inc.	Marietta, OH.
JMC (USA) Inc.	Research Triangle Park, NC.
Refractory:	
National Refractories and Minerals Corp.	Moss Landing, CA, and Columbiana, OH.
RHI Refractories America Inc.	Womelsdorf, PA.
Chemical:	
Elementis Chromium LP	Corpus Christi, TX.
Occidental Chemical Corp.	Castle Hayne, NC.

TABLE 3
U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL, BY END USE 1/

(Metric tons, gross weight, unless noted)

End use	Ferrochromium		Ferrochro-mium silicon	Other	Total
	Low-carbon 2/	High-carbon 3/			
1998:					
Steel:					
Carbon	4,440	7,950	138	W	12,500
Stainless and heat-resisting	7,230	226,000	W	W	233,000
Full-alloy	4,050	22,300	1,530	34 r/	28,000
High-strength, low-alloy, electric	2,170	1,790	W	W	3,960 r/
Tool	(4/)	W	W	W	W
Cast irons	(4/)	2,510	W	W	2,510
Superalloys	2,470	W	W	4,050	6,520
Welding materials 5/	161	249	W	W	409
Other alloys 6/	480	1,200	--	1,310	2,990 r/

See footnotes at end of table.

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TABLE 3--Contiuned
U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL, BY END USE 1/

(Metric tons, gross weight, unless noted)

End use	Ferrochromium		Ferrochro-mium silicon	Other	Total
	Low-carbon 2/	High-carbon 3/			
1998--Continued:					
Miscellaneous and unspecified	(4/)	6,540 r/	36,700 r/	3,190 r/	46,400 r/
Total 7/	21,000	268,000	38,300	8,580 r/ 8/	336,000
Chromium content	14,200	157,000	13,800	6,450 r/	192,000
Stocks, December 31, 1998	2,460	13,900	730	461 r/ 9/	17,500
1999:					
Steel:					
Carbon	4,100	6,330	165 r/	W	10,600
Stainless and heat-resisting	9,930 r/	274,000	W	W	284,000
Full-alloy	3,830	20,900 r/	1,410 r/	W	26,100 r/
High-strength, low-alloy, electric	2,130	2,300	W	W	4,430
Tool	(4/)	W	--	W	W
Cast irons	(4/)	1,720 r/	W	W	1,710
Superalloys	1,730	3,820	W	3,720	9,280
Welding materials 5/	219	232	1	363	815
Other alloys 6/	412	W	--	1,710	2,120 r/
Miscellaneous and unspecified	(4/)	2,010	44,800	3,240	50,000
Total 7/	22,300	312,000 r/	46,300	9,040 10/	390,000 r/
Chromium content	15,000	179,000 r/	16,300	6,720	217,000 r/
Stocks, December 31, 1999	2,200 r/	21,700 r/	769 r/	545 11/	25,200 r/
2000:					
Steel:					
Carbon	4,200	7,170	127	W	11,500
Stainless and heat-resisting	9,660	252,000	27,800	W	290,000
Full-alloy	4,230	22,100	1,640	50	28,000
High-strength, low-alloy, electric	2,730	9,880	(4/)	W	12,600
Tool	(4/)	W	(4/)	W	W
Cast irons	(4/)	2,090	(4/)	57	2,150
Superalloys	1,380	W	297	3,730	5,400
Welding materials 5/	203	243	1	W	447
Other alloys 6/	(4/)	W	--	1,550	1,550
Miscellaneous and unspecified	(4/)	5,370	(4/)	2,260	7,630
Total 7/	22,400	299,000	29,900	7,650 12/	359,000
Chromium content	15,200	174,000	10,200	6,470	206,000
Stocks, December 31, 2000	2,160	23,300	713	451 13/	26,600

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Contains less than 3% carbon.
3/ Contains 3% or more carbon.
4/ Withheld to avoid disclosing company proprietary data.
5/ Includes structural and hard-facing welding material.
6/ Includes cutting materials and magnetic, aluminum, copper, nickel, and other alloys.
7/ Includes estimates.
8/ Includes 4,670 tons of chromium metal.
9/ Includes 195 tons of chromium metal.
10/ Includes 4,690 tons of chromium metal.
11/ Includes 245 tons of chromium metal.
12/ Includes 4,980 tons of chromium metal.
13/ Includes 191 tons of chromium metal.

TABLE 4
U.S. GOVERNMENT STOCKPILE YEAREND INVENTORIES AND CHANGE FOR CHROMIUM-CONTAINING MATERIALS 1

(Metric tons, gross weight)

Material	1999	2000	Change	
			Quantity	Percentage 3/
Chromite ore:				
Chemical	205,000	203,000	(2,630)	(1)
Metallurgical	340,000	193,000	(147,000)	(43)
Refractory	274,000	241,000	(33,900)	(12)

See footnotes at end of table.

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TABLE 4--Continued
U.S. GOVERNMENT STOCKPILE YEAREND INVENTORIES AND CHANGE FOR CHROMIUM-CONTAINING MATERIALS 1

(Metric tons, gross weight)

Material	1999	2000	Change	
			Quantity	Percentage 3/
Chromium ferroalloys:				
Ferrochromium-silicon	50,700	34,200	(16,400)	(32)
High-carbon ferrochromium	645,000	615,000	(29,500)	(5)
Low-carbon ferrochromium	278,000	270,000	(7,760)	(3)
Chromium metal:				
Aluminothermic	2,670	2,500	(169)	(6)
Electrolytic	5,050	5,050	--	--

-- Zero.
1/ Includes specification- and nonspecification-grade materials.
2/ Data are rounded to no more than three significant digits.
3/ Quantity change as a percentage of stocks in earlier year.

Source: Defense Logistics Agency, Defense National Stockpile Center.

TABLE 5
TIME-VALUE RELATIONS FOR CHROMITE ORE, FERROCHROMIUM, AND CHROMIUM METAL 1/ 2.

(Annual average value, dollars per metric ton)

Material	1999		2000	
	Contained chromium	Gross weight	Contained chromium	Gross weight
Chromite ore:				
Not more than 40% chromic oxide	215	65	841	210
More than 40%, but less than 46% chromic oxide	866	266	178	56
46% or more chromic oxide	181	62	191	62
Average 3/	184	62	198	64
Ferrochromium:				
Not more than 3% carbon:				
Not more than 0.5% carbon	XX	XX	1,090	707
More than 0.5%, but not more than 3% carbon	XX	XX	1,540	1,000
Average 3/	1,560	1,040	1,470	956
More than 3%, but not more than 4% carbon	572	372	--	--
More than 4% carbon	658	387	710	409
Average 3/	723	429	797	466
Chromium metal	XX	6,270	XX	5,980

XX Not applicable. -- Zero.
1/ Based on Customs value of chromium contained in imported material.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Mass-weighted average.

TABLE 6
PRICE QUOTATIONS FOR CHROMIUM MATERIALS AT BEGINNING AND END OF 2000 1/

Material		January	December	Year average 2/
Chromite ore:				
South Africa	dollars per metric ton	60- 65	NA	NA
Turkey	do.	140-150	NA	NA
High-carbon ferrochromium, imported:				
50% to 55% chromium	cents per pound of chromium	37.00-40.00	39.00-41.00	41.44
60% to 65% chromium	do.	38.00-40.50	37.00-39.00	40.13
Low-carbon ferrochromium, imported:				
0.05% carbon	do.	67-70	60-65	69
0.10% carbon	do.	53-54	47-50	57
Chromium metal, domestic:				
Electrolytic, standard	cents per pound	415-470	435-445	443
Electrolytic, vacuum	do.	525-550	520-565	542

NA Not available.
1/ Sources: chromite ore and ferrochromium prices--Platt's Metals Week; chromium metal prices--American Metal Market.
2/ Time-weighted average.

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TABLE 7
U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE 1/

HTSUSA 2/	Type	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)	Principal destinations, 2000
2610.00.0000	Chromite ore and concentrate, gross weight	110,000,000	$8,580	138,000,000	$10,200	Sweden (92%); Canada (3%); Mexico (3%).
8112.20.0000	Metals and alloys, chromium metal, gross weight 3/	2,370,000	17,100	1,260,000	13,100	Japan (48%); Canada (26%); Germany (8%); Netherlands (4%); Mexico (3%); Australia (2%); Brazil (2%); Hong Kong (2%); Belgium (1%).
	Chromium ferroalloys:					
7202.41.0000	High-carbon ferrochromium, gross weight 4/	4,250,000	3,180	33,500,000	17,500	Switzerland (57%); Slovenia (30%); Canada (6%); Mexico (5%); Australia (2%).
7202.41.0000	High-carbon ferrochromium, contained weight 4/	2,550,000	--	22,200,000	--	
7202.49.0000	Low-carbon ferrochromium, gross weight 5/	1,290,000	1,560	1,570,000	2,180	Canada (41%); Mexico (40%); France (9%); United Kingdom (3%); India (2%); Sweden (2%); Venezuela (1%).
7202.49.0000	Low-carbon ferrochromium, contained weight 5/	776,000	--	945,000	--	
7202.50.0000	Ferrochromium-silicon, gross weight	250,000	243	2,700,000	1,490	Netherlands (98%); Canada (2%).
7202.50.0000	Ferrochromium-silicon, contained weight	87,700	--	946,000	--	
	Total ferroalloys, gross weight	5,790,000	4,980	37,700,000	21,200	
	Total ferroalloys, contained weight	3,420,000	--	24,100,000	--	
	Chemicals, gross weight:					
	Chromium oxides:					
2819.10.0000	Chromium trioxide	11,100,000	21,800	11,600,000	22,800	Canada (35%); Korea, Republic of (9%); Australia (6%); Japan (6%); Mexico (6%); Taiwan (6%); Brazil (5%); Germany (4%); New Zealand (4%); Indonesia (3%); Hong Kong (2%); Peru (2%); Singapore (2%); Thailand (2%); Chile (1%); Philippines (1%); South Africa (1%).
2819.90.0000	Other	3,310,000	13,400	5,170,000	20,300	Germany (40%); Canada (19%); United Kingdom (13%); Belgium (6%); Guinea (3%); Guatemala (3%); Taiwan (3%); China (2%); Malaysia (2%); Mexico (2%); Australia (1%); Japan (1%); Netherlands (1%).
2833.23.0000	Chromium sulfates	14,000	69	23,500	32	Canada (85%); Germany (15%).
	Salts of oxometallic or peroxometallic acids:					
2841.20.0000	Zinc and lead chromate	523,000	1,830	287,000	620	Mexico (42%); Canada (30%); India (13%); Dominican Republic (7%); Argentina (4%); Korea, Republic of (1%).
2841.30.0000	Sodium dichromate	26,500,000	17,500	19,400,000	14,400	Mexico (53%); Thailand (16%); Uruguay (8%); Panama (4%); Argentina (3%); Belgium (3%); Colombia (3%); Canada (1%); Germany (1%).
2841.40.0000	Potassium dichromate	82,600	151	95,400	144	Indonesia (79%); Canada (11%); South Africa (6%); Italy (2%); Dominican Republic (1%).
2841.50.0000	Other chromates, dichromates, and peroxochromates	297,000	893	639,000	2,140	Canada (55%); Korea, Republic of (23%); Mexico (8%); Malaysia (5%); Italy (4%); United Kingdom (2%).
3206.20.0000	Pigments and preparations, gross weight	1,470,000	6,200	1,040,000	5,340	Mexico (41%); Canada (33%); Costa Rica (5%); Trinidad and Tobago (3%); Belgium (2%); Colombia (2%); Nigeria (2%); Singapore (2%); Taiwan (2%); Brazil (1%); Venezuela (1%).

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.
3/ Articles thereof and waste and scrap.
4/ More than 4% carbon.
5/ Not more than 4% carbon.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF CHROMITE ORE, BY COUNTRY 1/

Country	Not more than 40% Cr_2O_3 (HTS 2610.00.0020) 2/			More than 40%, but less than 46% Cr_2O_3 (HTS 2610.00.0040) 2/			46% or more Cr_2O_3 (HTS 2610.00.0060) 2/			Total		
	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value 3/ (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value 3/ (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value 3/ (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value 3/ (thousands)
1999:												
Canada	380	146	$168	40	19	$11	57	18	$10	477	183	$189
Philippines	4,000	1,320	456	--	--	--	--	--	--	4,000	1,320	456
South Africa	21,100	9,710	1,020	49	21	12	226,000	113,000	14,000	247,000	123,000	15,000
Total	25,500	11,200	1,650	89	40	24	226,000	113,000	14,000	252,000	124,000	15,700
2000:												
Canada	1,130	440	541	68	29	36	86	43	14	1,290	512	592
Italy	--	--	--	--	--	--	32	15	6	32	15	6
Philippines	3,390	1,210	409	--	--	--	--	--	--	3,390	1,210	409
South Africa	--	--	--	33,100	15,100	1,810	230,000	109,000	14,300	263,000	125,000	16,100
Total	4,520	1,650	950	33,100	15,100	1,840	230,000	109,000	14,300	268,000	126,000	17,100

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Harmonized Tariff Schedule of the United States of America code.

3/ Customs import value generally represents a value in the foreign country and therefore excludes U.S. import duties, freight, insurance and other charges incurred in bringing the merchandise to the United States.

Source: U.S. Census Bureau.

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TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY 1/

Country	Not more than 3% carbon (HTS 7202.49.5000) 2/			More than 3% carbon, but not more than 4% carbon (HTS 7202.49.1000) 2/			More than 4% carbon (HTS 7202.41.0000) 2/			Total (all grades)		
	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)
1999:												
Albania	--	--	--	--	--	--	3,750	2,360	$1,780	3,750	2,360	$1,780
China	758	511	$927	--	--	--	4,360	2,590	2,380	5,120	3,100	3,310
Finland	--	--	--	--	--	--	5,060	2,780	1,940	5,060	2,780	1,940
France	--	--	--	--	--	--	6	4	7	6	4	7
Germany	6,840	4,780	14,000	--	--	--	--	--	--	6,840	4,780	14,000
India	--	--	--	--	--	--	5,010	3,090	1,930	5,010	3,090	1,930
Japan	1,010	697	2,330	--	--	--	--	--	--	1,010	697	2,330
Kazakhstan	3,960	2,770	3,060	--	--	--	154,000	106,000	68,500	158,000	108,000	71,500
Russia	16,800	11,500	13,200	--	--	--	7,830	5,230	5,070	24,600	16,700	18,300
South Africa	5,950	3,440	3,970	--	--	--	229,000	114,000	69,900	235,000	117,000	73,900
Sweden	34	24	74	--	--	--	--	--	--	34	24	74
Turkey	--	--	--	--	--	--	83,700	52,500	31,900	83,700	52,500	31,900
United Kingdom	61	43	131	3,000	1,950	$1,120	2	1	2	3,060	1,990	1,250
United States	--	--	--	--	--	--	4	3	12	4	3	11
Zimbabwe	3,590	2,380	2,900	--	--	--	68,400	42,300	34,100	72,000	44,700	37,000
Total	39,000	26,100	40,700	3,000	1,950	1,120	562,000	331,000	218,000	604,000	359,000	259,000
2000:												
Brazil	40	25	$90	--	--	--	--	--	--	40	25	$90
China	159	111	236	60	42	$73	192	126	$147	411	279	456
Croatia	--	--	--	--	--	--	8,450	5,300	3,630	8,450	5,300	3,630
Georgia	130	91	213	--	--	--	--	--	--	130	91	213
Germany	7,520	5,090	14,400	23	16	74	--	--	--	7,540	5,110	14,500
India	--	--	--	--	--	--	3,850	2,260	1,610	3,850	2,260	1,610
Japan	1,940	1,330	4,320	114	79	266	--	--	--	2,060	1,410	4,590
Kazakhstan	4,620	3,210	3,300	1,850	1,300	1,250	131,000	89,900	60,500	138,000	94,400	65,000
Russia	32,200	20,300	24,700	2,690	1,840	1,890	7,040	4,630	4,110	41,900	26,700	30,700
South Africa	451	293	662	2,960	1,680	1,760	260,000	131,000	91,700	264,000	133,000	94,100
Sweden	39	28	87	133	95	282	--	--	--	172	123	369
Turkey	2,960	2,140	2,190	--	--	--	45,800	28,400	20,500	48,800	30,500	22,700
United Kingdom	23	16	23	--	--	--	--	--	--	23	16	23
Zimbabwe	220	148	145	1,320	881	877	60,400	36,800	29,500	61,900	37,800	30,500
Total	50,300	32,700	50,400	9,150	5,930	6,470	517,000	298,000	212,000	577,000	337,000	269,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Harmonized Tariff Schedule of the United States of America code.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE 1/

HTS 2/	Type	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)	Principal sources, 2000
	Metals and alloys:					
	Chromium metal:					
8112.20.3000	Waste and scrap, gross weight	17,800	$150	40,700	$598	Russia (30%); United Kingdom (26%); Netherlands (13%); China (12%); Germany (12%); Singapore (5%); Mexico (1%).
8112.20.6000	Other than waste and scrap, gross weight	9,010,000	56,400	9,900,000	58,800	China (25%); Russia (25%); France (24%); United Kingdom (21%); Kazakhstan (2%); Germany (1%).
7202.50.0000	Ferrochromium-silicon, gross weight	36,000,000	18,700	20,700,000	10,300	Kazakhstan (46%); Russia (30%); Zimbabwe (18%); South Africa (6%).
7202.50.0000	Ferrochromium-silicon, contained weight	12,700,000	--	7,670,000	--	
	Chemicals (gross weight):					
	Chromium oxides and hydroxides:					
2819.10.0000	Chromium trioxide	6,730,000	12,000	8,030,000	13,700	Kazakhstan (68%); China (11%); Turkey (10%); Italy (5%); Poland (2%); Japan (1%); United Kingdom (1%).
2819.90.0000	Other	4,300,000	14,800	3,220,000	12,100	Japan (28%); China (25%); Germany (25%); United Kingdom (10%); Poland (4%); Netherlands (3%); Austria (2%); Belgium (1%); Colombia (1%); France (1%); Turkey (1%).
2833.23.0000	Sulfates of chromium	391,000	386	239,000	227	United Kingdom (46%); Mexico (30%); Poland (15%); Argentina (8%); Germany (1%).
	Salts of oxometallic or peroxometallic acids:					
2841.20.0000	Chromates of lead and zinc	159,000	355	289,000	563	Norway (38%); Canada (23%); Korea, Republic of (21%); China (9%); United Kingdom (6%); Japan (3%).
2841.30.0000	Sodium dichromate	10,400,000	7,770	16,900,000	10,500	United Kingdom (98%); China (2%).
2841.40.0000	Potassium dichromate	177,000	329	205,000	392	United Kingdom (45%); India (20%); Kazakhstan (20%); Netherlands (10%); Canada (5%); Japan (1%).
2841.50.0000	Other chromates and dichromates; peroxochromates	471,000	1,050	56,900	183	Korea, Republic of (49%); Austria (30%); United Kingdom (20%); India (2%).
2849.90.2000	Chromium carbide	252,000	2,870	182,000	2,010	Japan (48%); Germany (37%); United Kingdom (12%); Canada (2%); Austria (1%).
	Pigments and preparations based on chromium (gross weight):					
3206.20.0010	Chrome yellow	6,760,000	19,000	7,000,000	18,700	Canada (54%); Korea, Republic of (11%); Mexico (11%); Hungary (9%); China (8%); Colombia (4%); Japan (1%).
3206.20.0020	Molybdenum orange	1,550,000	6,600	1,620,000	7,110	Canada (87%); Mexico (6%); Philippines (3%); China (1%); Colombia (1%); Germany (1%); Hungary (1%); Japan (1%).
3206.20.0030	Zinc yellow	34,000	32	19,000	21	Brazil (89%); Colombia (5%); Italy (5%).
3206.20.0050	Other	1,250,000	4,330	1,530,000	6,290	China (39%); France (39%); Germany (10%); Canada (4%); Poland (2%); Belgium (1%); Japan (1%); Korea, Republic of (1%); Switzerland (1%); United Arab Emirates (1%).

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.

Source: U.S. Census Bureau.

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TABLE 11
PRINCIPAL WORLD CHROMITE ORE PRODUCERS, 2000

Country 1/	Company
Albania	Albkrom (Government owned).
Brazil	Cia. de Ferro Ligas da Bahia S.A.
	Elkem ASA (Norway).
	Mineracão Vila Nova Ltda.
	Magnesita S.A.
China	Huazang Smelter.
	Shashen.
	Xizang Kangjinla.
	Xinjiang Karamay Gold Mine.
	Xinjiang Nonferrous Metals Industry Co.
Finland	Outokumpu Oy;
	Outokumpu Steel Oy;
	Outokumpu Chrome Oy.
India	Ferro Alloys Corp. Ltd.
	Indian Metals and Ferroalloys Ltd.
	Indian Charge Chrome Ltd.
	Misrilall Mines Ltd.
	Mysore Mineral Ltd.
	Orissa Mining Corp. Ltd.
	Tata Iron and Steel Co. Ltd.
Indonesia	PT. Palabim Mining-PT. Bituminusa.
Iran	Faryab Mining Co.
Kazakhstan	Donskoy Ore Dressing Complex.
Madagascar	Kraomita Malagasy.
Oman	Oman Chromite Company SAOG.
Philippines	Benguet Corporation.
	Heritage Resources & Mining Corporation.
	Krominco Inc.
	Velore Mining Corporation.
Russia	Saranov Complex.
South Africa	ASA Metals (Pty.) Ltd.
	African Mining and Trust Co. Ltd.
	Rustenburg Minerals Development Co. (Pty.) Ltd.
	Zeerust Chrome Mine Ltd.
	Bafokeng Chrome Holdings.
	Bayer AG (Germany).
	Bayer (Pty.) Ltd.
South Africa--Continued	Canadian Gold S.A. (Pty.) Ltd.
	Goudini Chrome (Pty.) Ltd.
	Hernic Ferrochrome (Pty.) Ltd.
	National Manganese Mines Pty. Ltd.
	Pilanesberg Chrome (Pty.) Ltd.
	Rooderand Chrome Mine (Pty.) Ltd.
	South Africa Chrome and Alloys Ltd.
	Chromden Mine.
	Horizon Chrome Mine.
	Samancor Ltd.
	Eastern Chrome Mines.
	Western Chrome Mines.
	Vereeniging Refractories Ltd.
	Bophuthatswana Chrome Co. (Pty.) Ltd.
	Marico Chrome Corp. (Pty.) Ltd.
	Xstrata A.G. (Switzerland).
	Xstrata S.A. (Pty.) Ltd.
	Chromecorp (Pty.) Ltd.
	Consolidated Metallurgical Industries Ltd.
Sudan	Advanced Mining Works Co. Ltd.
Turkey	Aycan Madencilik Ltd. Sti.
	Bilfer Madencilik A.S.
	Birlik Madencilik Dis Tic. Insaat San. ve Tic. A.S
	Cevher Madencilik ve Ticaret A.S.
	Dedeman Madencilik Sanayi ve Ticaret A.S.
	Eti Holdings A.S.
	Hâyri Ögelman Mining Co. Ltd.
	Pinarbasi Madencilik Sanayi ve Ticaret Ltd.
	Tekfen Dis. Ticaret A.S.
	Tevfik Refik Bayoglu Madencilik.
	Tut. Gen. Ticaret Ltd. Sti.
	Türk Maadin A.S.
United Arab Emirates	Derkek Raphael & Co.
	Dewent Mining Ltd.
Zimbabwe	Maranatha Ferrochrome (Pvt.) Ltd.
	Amble Mining Co.
	Zimasco (Pvt.) Ltd.
	Zimbabwe Alloys Ltd.

1/ Other chromite-producing countries included Burma, Cuba, Pakistan, and Vietnam.

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TABLE 12
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 2000

Country 1/	Company
Albania	Albkrom (Government owned).
Brazil	Cia. de Ferro Ligas da Bahia S.A.
Chile	Carbomet Industrial SA.
China	Dandong Ferroalloy Plant.
	Emei Ferroalloy (Group) Co. Ltd.
	Gansu Huazang Metallurgical Group Co. Ltd.
	Hanzhong Ferroalloy Works (Government owned).
	Hengshang Iron & Steel.
	Hunan Ferroalloy (Government owned).
	Hunan Lengshuijiang Electrochemical Works.
	Jiangyin Ferroalloy Factory (Government owned).
	Jilin Dongfeng Ferroalloy Works.
	Jilin Ferroalloy Group Co. Ltd.
	Jilin Huinan Ferroally Works.
	Jinzhou Ferroalloy (Group) Co. Ltd.
	Liaoyang Ferroalloy Group Corp.
	Nanjing Ferroalloy Plant (Government owned).
	Ningjin Metal Smelting Co. Ltd.
	Qinghai Datong Ferroalloy Works
	Quinhai Sanchuan Ferroalloy Co. Ltd.
	Taonan Ferroalloy Works.
	Urad Zhongqi Ferrochrome Group Corp.
	Xibei Ferroalloy Works (Government owned).
	Zhejiang Hengshan Ferroalloy Works.
Croatia	Dalmacija Ferro-Alloys Works.
Finland	Outokumpu Oy;
	Outokumpu Steel Oy;
	Outokumpu Chrome Oy.
Germany	Elektrowerk Weisweiler GmbH.
India	Andhra Ferro Alloys Ltd.
	Baheti Metal & Ferro Alloys Ltd.
	Bharat Thermite Ltd.
	Deepak Ferro Alloys Ltd.
	Eastern Metals & Ferro Alloys Ltd.
	Ferro Alloys Corp. Ltd.
	Charge Chrome Plant.
	Ferro-Alloys Unit.
	GMR Vasavi Industries Ltd.
	Hi-Tech Electrothermics Ltd.
	Indian Metals and Ferroalloys Ltd.
	Indian Charge Chrome Ltd.
	Industrial Development Corp.
	Ispat Alloys Ltd.
	Jindal Strips Ltd.
	Ferro Alloys Division.
	Mandsaur Ferro Alloys Ltd.
	Metramet Ferroalloys Pvt. Ltd.
	Monnet Industries Ltd.
	Nav Chrome Ltd.
	Nava Bharat Ferro Alloys Ltd.
	Raghuvir Ferro Alloy Pvt. Ltd.
	Shri Girija Smelters Ltd.
India--Continued:	Srinivasa Ferro Alloys Ltd.
	Standard Chrome Ltd.
	The Sandur Manganese & Iron Ores Ltd.
	Tata Iron and Steel Co. Ltd.
	Bamnipal Plant.
	Joda Plant.
	VBC Ferro Alloys Ltd.
	V.K. Ferro Alloys Private Ltd.
Iran	Faryab Mining Co.
	Abadan Ferroalloys Refinery.
Italy	Darfo S.p.A.
	Fornileghe S.p.A.
	Mineralsider S.p.A.
Japan	Nippon Denko Co. Ltd.
	NKK Corp.
	NKK Materials Co. Ltd.
	Showa Denko K.K.
	Shunan Denko K.K.
Kazakhstan	Aksusky Ferroalloy Plant.
	Aktyubinsk Ferroalloy Plant.
Norway	Elkem ASA.
Poland	Huta "Laziska" Ferroalloy Plant.
Russia	Chelyabinsk Electrometallurgical Integrated Plant
	Klutchevsk Ferroalloy Plant.
	Metall Joint Venture.
	Serov Ferroalloys Plant.
Slovakia	Oravske Ferozliatinarske Zavody.
Slovenia	Tovarna Dusika Ruse-Metalurgija d.d.
South Africa	ASA Metals (Pty.) Ltd.
	Associated Manganese Mines of South Africa Ltc
	Feralloys Ltd.
	Hernic Ferrochrome (Pty.) Ltd.
	Samancor Ltd.
	Batlhako Ferrochrome Ltd.
	Ferrometals Division.
	Middelburg Ferrochrome Division.
	Palmiet Ferrochrome Division.
	Tubatse Ferrochrome Division.
	Xstrata A.G. (Switzerland).
	Xstrata S.A. (Pty.) Ltd.
	Chromecorp (Pty.) Ltd.
	Consolidated Metallurgical Industries Ltd.
	Lydenburg Works.
	Rustenburg Works.
Sweden	Vargön Alloys AB.
Turkey	Eti Holdings A.S.
	Eti Elektromatalurji.
	Eti Krom A.S.
United States	Eramet Marietta Inc.
Zimbabwe	Maranatha Ferrochrome (Pvt.) Ltd.
	Zimasco (Pvt.) Ltd.
	Zimbabwe Alloys Ltd.

1/ Other ferrochromium-producing countries include Spain and Taiwan.

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TABLE 13
ANNUAL WORLD PRODUCTION CAPACITY OF CHROMITE ORE, FERROCHROMIUM, CHROMIUM METAL, CHROMIUM CHEMICALS, AND STAINLESS STEEL IN 2000 1/

(Thousand metric tons, contained chromium)

Country	Ore	Ferro-chromium	Metal	Chemicals	Stainless steel
Albania	48	27	--	--	--
Argentina	--	--	--	6	--
Austria	--	--	--	--	8
Bangladesh	--	--	--	--	3
Belgium	--	--	--	--	119
Brazil	135	62	--	--	41
Burma	1	--	--	--	--
Canada	--	--	--	--	39
Chile	--	1	--	--	--
China	48	272	6	21	60
Croatia	--	17	--	--	--
Cuba	15	--	--	--	7
Czech Republic	--	--	--	--	5
Finland	184	128	--	--	102
France	--	--	7	--	204
Germany	--	17	1	--	255
Greece	4	--	--	--	--
India	462	183	(2/)	8	111
Indonesia	4	--	--	--	--
Iran	112	9	--	2	--
Italy	--	32	--	--	204
Japan	--	113	1	17	660
Kazakhstan	903	398	2	42	--
Korea, Republic of	--	--	--	--	306
Macedonia	2	--	--	5	--
Madagascar	42	--	--	--	--
Norway	--	106	--	--	--
Oman	9	--	--	--	--
Pakistan	8	--	--	3	--
Philippines	33	--	--	--	--
Poland	--	12	--	5	--
Romania	--	--	--	9	--
Russia	46	180	16	60	60
Slovakia	--	38	--	--	--
Slovenia	--	15	--	--	13
South Africa	2,060	1,500	--	24	95
Spain	--	1	--	--	204
Sudan	14	--	--	--	--
Sweden	--	86	--	--	128
Taiwan	--	1	--	--	167
Turkey	626	69	--	10	54
Ukraine	--	--	--	--	33
United Arab Emirates	23	--	--	--	--
United Kingdom	--	--	7	52	92
United States	--	20	3	56	390
Vietnam	16	--	--	--	--
Zimbabwe	213	227	--	--	--
Total	5,010	3,510	43	320	3,360

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

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TABLE 14
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	World total	Afghanistan	Albania 3/	Argentina	Australia	Brazil 4/	Burma	Canada	China	Colombia	Cuba	Cyprus 6/	Egypt 7/	Finland
1900	53,200	NA	--	NA	3,340	NA	NA	NA	--	--	--	--	--	--
1901	90,200	NA	--	NA	2,520	NA	NA	NA	--	--	--	--	--	--
1902	85,300	NA	--	NA	454	NA	NA	NA	--	--	--	--	--	--
1903	95,500	NA	--	NA	1,980	NA	NA	NA	--	--	--	--	--	--
1904	118,000	NA	--	NA	403	NA	NA	NA	--	--	--	--	--	--
1905	144,000	NA	--	NA	53	NA	NA	NA	--	--	--	--	--	--
1906	161,000	NA	--	NA	15	NA	NA	NA	--	--	--	--	--	--
1907	112,000	NA	--	NA	30	NA	NA	NA	--	--	--	--	--	--
1908	67,000	NA	--	NA	--	NA	NA	NA	--	--	--	--	--	--
1909	108,000	NA	--	NA	--	NA	NA	NA	--	--	--	--	--	--
1910	108,000	NA	--	NA	--	NA	NA	NA	--	--	--	--	--	--
1911	81,100	NA	--	NA	--	NA	NA	NA	--	--	--	--	--	--
1912	123,000	NA	--	NA	23	NA	NA	NA	--	--	--	--	--	--
1913	147,000	NA	--	NA	688	NA	NA	NA	--	--	--	--	--	--
1914	157,000	NA	--	NA	659	NA	NA	NA	--	--	--	--	--	--
1915	185,000	NA	--	NA	769	NA	NA	NA	--	--	--	--	--	--
1916	281,000	NA	--	NA	621	NA	NA	NA	--	--	35	--	--	--
1917	263,000	NA	--	NA	1,140	NA	NA	NA	--	--	17	--	--	--
1918	312,000	NA	--	NA	611	NA	NA	NA	--	--	8,960	--	--	--
1919	171,000	NA	--	NA	254	NA	NA	NA	--	--	14,700	--	--	--
1920	172,000	NA	--	NA	1,640	NA	NA	NA	--	--	721	--	--	--
1921	134,000	NA	--	NA	63	NA	NA	NA	--	--	610	--	--	--
1922	140,000	NA	--	NA	537	NA	NA	NA	--	--	--	--	--	--
1923	205,000	NA	--	NA	1,210	NA	NA	NA	--	--	10,600	--	--	--
1924	292,000	NA	--	NA	785	NA	NA	NA	--	--	19,900	2,860	--	--
1925	308,000	NA	--	NA	978	NA	NA	NA	--	--	30,300	2,020	--	--
1926	363,000	NA	--	NA	607	NA	NA	NA	--	--	36,600	650	--	--
1927	400,000	NA	--	NA	--	NA	NA	NA	--	--	17,300	723	--	--
1928	452,000	NA	--	NA	--	NA	NA	NA	--	--	34,200	--	--	--
1929	635,000	NA	--	NA	131	NA	NA	NA	--	--	53,800	2,480	--	--
1930	559,000	NA	--	NA	171	NA	NA	NA	--	--	41,600	1,570	--	--
1931	383,000	NA	--	NA	26	NA	NA	NA	--	--	15,200	203	--	--
1932	299,000	NA	--	NA	99	NA	NA	NA	--	--	500	1,000	--	--
1933	409,000	NA	--	NA	905	NA	NA	NA	--	--	24,200	--	--	--
1934	619,000	NA	--	NA	1,740	NA	NA	NA	--	--	50,200	982	--	--
1935	785,000	NA	--	NA	605	NA	NA	NA	--	--	48,500	1,200	--	--
1936	1,060,000	NA	--	NA	422	NA	NA	NA	--	--	71,100	508	--	--
1937	1,280,000	NA	--	NA	466	NA	NA	NA	--	--	94,600	1,640	--	--
1938	1,140,000	NA	499	NA	952	NA	NA	NA	--	--	33,600	5,670	--	--
1939	1,190,000	NA	3,080	NA	118	NA	NA	NA	--	--	59,600	1,120	--	--
1940	1,460,000	NA	14,000	NA	500	NA	NA	NA	--	--	52,300	2,540	--	--
1941	1,660,000	NA	20,000	NA	356	NA	NA	NA	--	--	163,000	4,820	--	--
1942	2,030,000	NA	38,100	NA	365	NA	NA	NA	--	--	286,000	2,940	312	--
1943	1,820,000	NA	30,800	NA	1,000	NA	NA	NA	--	--	354,000	7,990	910	--

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	World total	Afghanistan	Albania 3/	Argentina	Australia	Brazil 4/	Burma	Canada	China	Colombia	Cuba	Cyprus 6/	Egypt 7/	Finland
1944	1,400,000	NA	--	NA	780	NA	NA	NA	--	--	192,000	469	150	--
1945	1,060,000	NA	--	NA	287	NA	NA	NA	--	--	173,000	1,070	150	--
1946	1,170,000	NA	--	NA	--	NA	NA	NA	--	--	174,000	1,160	--	--
1947	1,730,000	NA	--	NA	--	NA	NA	NA	--	--	159,000	5,280	266	--
1948	2,130,000	NA	16,500	NA	564	NA	NA	NA	--	--	117,000	6,900	191	--
1949	2,150,000	NA	39,900	NA	642	NA	NA	NA	--	--	97,400	14,900	50	--
1950	2,360,000	550	52,000	--	905	3,230	--	--	--	--	65,800	18,400	36	--
1951	2,810,000	75	45,400	--	1,400	2,420	--	--	--	--	79,100	12,700	--	--
1952	3,360,000	--	51,700	--	1,420	2,650	--	--	--	--	61,800	13,500	--	--
1953	3,900,000	--	47,000	--	2,790	3,580	--	--	--	--	70,000	8,270	210	--
1954	3,270,000	--	100,000	--	5,020	1,910	--	--	--	--	72,600	9,140	530	--
1955	3,650,000	--	122,000	--	--	4,120	--	--	--	--	77,200	8,710	840	--
1956	4,140,000	--	132,000	--	6,190	4,110	--	--	--	--	53,700	5,310	255	--
1957	4,640,000	--	167,000	--	3,100	7,940	--	--	--	--	115,000	5,150	103	--
1958	3,830,000	--	201,000	--	788	5,290	--	--	--	--	75,100	12,000	--	--
1959	3,910,000	--	248,000	--	122	6,220	--	--	--	50	39,700	12,400	250	--
1960	4,430,000	--	289,000	--	537	5,670	--	--	--	70	29,700	14,200	300	--
1961	4,200,000	--	232,000	--	--	15,500	--	--	--	185	25,400	18,000	1,390	--
1962	4,410,000	--	251,000	--	375	24,800	--	--	--	140	35,400	6,540	--	--
1963	3,910,000	--	294,000	--	163	17,100	--	--	--	110	56,600	4,910	--	--
1964	4,160,000	--	307,000	--	73	9,440	--	--	--	400	--	2,990	--	--
1965	4,810,000	--	310,000	--	23	17,000	--	--	--	260	--	4,990	--	--
1966	4,390,000	--	313,000	--	--	15,000	--	--	--	--	--	10,500	--	NA
1967	4,570,000	--	327,000	--	140	15,000	--	--	--	--	--	21,800	--	6,380
1968	4,940,000	--	388,000	--	--	17,000	--	--	--	--	--	25,100	--	36,200
1969	5,321,000	--	429,000	--	--	15,000	--	--	--	(5/)	--	24,000	0	72,000
1970	6,053,000	--	468,000	--	--	27,000	--	--	--	(5/)	--	34,000	0	121,000
1971	6,435,000	--	502,000	(5/)	--	28,000	--	--	--	1,000	20,000	42,000	0	112,000
1972	6,101,000	--	558,000	--	--	71,000	--	--	--	(5/)	20,000	24,000	0	97,000
1973	6,696,000	--	611,000	--	--	73,000	--	--	--	12,000	20,000	30,000	1,000	148,000
1974	7,461,000	--	715,000	(5/)	--	108,000	--	--	--	12,000	20,000	34,000	(5/)	165,000
1975	8,288,000	--	779,000	--	--	173,000	--	--	--	12,000	32,000	27,000	(5/)	331,000
1976	8,493,000	--	830,000	--	--	186,000	--	--	--	5,000	19,000	9,000	(5/)	175,000
1977	9,448,000	--	880,000	--	--	310,000	--	--	--	--	20,000	15,000	1,000	402,000
1978	10,944,000	--	989,000	--	--	958,000	--	--	--	--	29,000	15,000	1,000	407,000
1979	9,323,000	--	750,000	--	--	340,000	--	--	--	--	28,000	15,000	(5/)	435,000
1980	9,902,000	--	762,000	--	--	313,000	--	--	--	--	28,000	16,000	--	362,000
1981	9,088,000	--	710,000	--	--	237,000	--	--	--	--	21,000	10,000	--	412,000
1982	8,480,000	--	675,000	--	--	276,000	--	--	--	--	27,000	3,000	--	345,000
1983	8,210,000	--	685,000	--	--	161,000	--	--	--	--	34,000	--	--	246,000
1984	9,780,000	--	720,000	--	--	260,000	--	--	--	--	37,900	--	--	446,000
1985	10,900,000	--	825,000	--	--	190,000	--	--	--	--	37,700	--	--	506,000
1986	11,800,000	--	850,000	--	--	353,000	--	--	50,000	--	50,000	--	--	678,000
1987	11,900,000	--	1,080,000	--	--	338,000	--	--	32,000	--	52,400	--	--	543,000

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	World total	Afghanistan	Albania 3/	Argentina	Australia	Brazil 4/	Burma	Canada	China	Colombia	Cuba	Cyprus 6/	Egypt 7/	Finland
1988	12,900,000	--	1,110,000	--	--	410,000	--	--	26,000	--	52,200	--	800	700,000
1989	14,000,000	--	900,000	--	--	476,000	5,000	--	25,000	--	50,600	--	2,450	513,000
1990	13,200,000	--	957,000	--	--	263,000	1,000	--	25,000	--	50,000	--	399	504,000
1991	13,300,000	--	587,000	--	--	340,000	1,000	--	25,000	--	50,000	--	649	473,000
1992	11,100,000	--	322,000	--	--	449,000	6,200	--	25,000	--	10,400 r/	--	600	499,000
1993	9,300,000	--	115,000	--	--	308,000	1,000	--	54,000	--	17,600 r/	--	--	511,000
1994	10,400,000	--	118,000	--	--	360,000	1,000	--	62,000	--	28,800 r/	--	--	573,000
1995	14,000,000	--	160,000	--	--	448,000	1,000	--	94,000	--	30,700 r/	--	--	598,000
1996	11,600,000	--	143,763 r/	--	6,000	408,495	1,000 e/	--	130,000 e/	--	37,300	--	--	582,000 r/
1997	13,700,000 r/	--	106,304 r/	--	31,000	300,000	3,299	--	200,000 r/ e/	--	44,000	--	--	589,000
1998	13,400,000 r/	--	102,189 r/	--	130,000	301,000 r/	4,059	--	21,000 r/ e/	--	49,044	--	--	610,000 r/ e/
1999	14,100,000 r/	--	71,434 r/	--	130,000 e/	420,000 r/ e/	3,200 e/	--	-- r/ e/	--	35,750	--	--	635,000 r/ e/
2000 e/	14,400,000	--	70,000	--	130,000	400,000	3,000	--	--	--	40,000	--	--	640,000

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Greece	Guatemala	India	Indonesia	Iran	Japan	Kazakh-stan 8/	Macedo-nia 10/	Madaga-scar 11/	Morocco	New Caledonia	Oman	Pakistan 12/	Philippines
1900	5,600	NA	--	--	--	--	XX	XX	--	--	13,000	--	XX	--
1901	4,850	NA	--	--	--	--	XX	XX	--	--	17,600	--	XX	--
1902	11,700	NA	--	--	--	--	XX	XX	--	--	17,500	--	XX	--
1903	8,480	NA	260	--	--	--	XX	XX	--	--	34,400	--	XX	--
1904	15,400	NA	3,650	--	--	--	XX	XX	--	--	47,200	--	XX	--
1905	8,900	NA	2,750	--	--	--	XX	XX	--	--	76,900	--	XX	--
1906	11,500	NA	4,450	--	--	--	XX	XX	--	--	84,200	--	XX	--
1907	11,700	NA	7,390	--	--	--	XX	XX	--	--	29,800	--	XX	--
1908	4,350	NA	4,820	--	--	--	XX	XX	--	--	15,800	--	XX	--
1909	9,600	NA	9,400	--	--	--	XX	XX	--	--	40,000	--	XX	--
1910	9,460	NA	1,770	--	--	2,120	XX	XX	--	--	40,000	--	XX	--
1911	4,610	NA	3,860	--	--	1,520	XX	XX	--	--	21,900	--	XX	--
1912	6,470	NA	2,940	--	--	1,620	XX	XX	--	--	27,300	--	XX	--
1913	6,340	NA	5,770	--	--	1,330	XX	XX	--	--	45,900	--	XX	--
1914	7,060	NA	5,980	--	--	2,120	XX	XX	--	--	71,100	--	XX	--
1915	10,400	NA	3,830	--	--	2,990	XX	XX	--	--	82,100	--	XX	--
1916	9,880	NA	20,500	--	--	8,280	XX	XX	--	--	69,700	--	XX	--
1917	6,750	NA	27,500	--	--	8,940	XX	XX	--	--	54,800	--	XX	--
1918	10,900	NA	58,700	--	--	6,250	XX	XX	--	--	55,200	--	XX	--
1919	8,050	NA	37,000	--	--	6,010	XX	XX	--	--	46,400	--	XX	--
1920	7,380	NA	27,200	--	--	3,970	XX	XX	--	--	31,300	--	XX	--
1921	8,030	NA	35,300	--	--	3,370	XX	XX	--	--	22,900	--	XX	--
1922	9,210	NA	23,100	--	--	3,760	XX	XX	--	--	13,200	--	XX	--
1923	14,800	NA	55,100	--	--	4,530	XX	XX	--	--	24,100	--	XX	--
1924	15,100	NA	46,200	--	--	5,360	XX	XX	--	--	23,000	--	XX	--
1925	8,080	NA	38,100	--	--	5,820	XX	XX	--	--	34,700	--	XX	--
1926	20,000	NA	33,900	--	--	7,050	XX	XX	--	--	33,200	--	XX	--
1927	17,300	NA	58,100	--	--	9,780	XX	XX	--	--	33,500	--	XX	--
1928	21,000	NA	46,200	--	--	9,810	XX	XX	--	--	50,800	--	XX	--
1929	24,200	NA	50,400	--	--	9,160	XX	XX	--	--	52,600	--	XX	--
1930	23,400	NA	51,500	--	--	11,300	XX	XX	--	--	61,900	--	XX	--
1931	5,630	NA	20,200	--	--	9,070	XX	XX	--	--	74,100	--	XX	--
1932	1,550	NA	18,200	--	--	12,500	XX	XX	--	--	69,400	--	XX	--
1933	14,800	NA	15,800	--	--	19,900	XX	XX	--	--	50,100	--	XX	--
1934	30,700	NA	21,900	--	--	27,200	XX	XX	--	--	55,200	--	XX	--
1935	29,800	NA	39,800	--	--	28,800	XX	XX	--	--	55,300	--	XX	1,290
1936	47,300	NA	50,800	--	--	35,100	XX	XX	--	--	47,800	--	XX	11,900
1937	52,600	NA	63,300	--	--	45,000	XX	XX	--	--	48,000	--	XX	69,900
1938	42,500	NA	44,900	--	--	52,800	XX	XX	--	--	52,200	--	XX	66,900
1939	57,100	NA	49,900	--	--	57,400	XX	XX	--	--	57,300	--	XX	134,000
1940	29,700	NA	56,400	--	--	56,700	XX	XX	--	--	55,800	--	XX	204,000
1941	16,200	NA	50,900	--	--	54,500	XX	XX	--	--	64,500	--	XX	233,000
1942	24,300	NA	50,400	--	435	67,500	XX	XX	--	--	67,600	--	XX	49,900
1943	15,500	NA	33,800	--	1,270	58,500	XX	XX	--	--	47,000	--	XX	59,900

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Greece	Guatemala	India	Indonesia	Iran	Japan	Kazakh-stan 8/	Macedo-nia 10/	Madaga-scar 11/	Morocco	New Caledonia	Oman	Pakistan 12/	Philippines
1944	18,300	NA	40,200	--	12	71,100	XX	XX	--	--	55,200	--	XX	69,900
1945	2,410	NA	31,600	--	--	28,500	XX	XX	--	--	59,800	--	XX	--
1946	9,060	NA	45,500	--	--	7,080	XX	XX	--	--	24,900	--	XX	58,900
1947	2,640	NA	35,300	--	--	2,410	XX	XX	--	--	50,500	--	22,000	195,000
1948	1,500	NA	22,900	--	--	9,340	XX	XX	--	--	75,000	--	18,200	257,000
1949	3,720	NA	19,700	--	--	27,100	XX	XX	--	--	89,000	--	17,200	247,000
1950	12,600	289	17,000	--	--	33,000	XX	XX	--	--	84,800	--	18,400	251,000
1951	25,300	1,140	17,000	--	8,830	40,900	XX	XX	--	--	88,800	--	18,000	335,000
1952	32,200	105	36,800	--	20,000	47,200	XX	XX	--	--	108,000	--	17,700	544,000
1953	36,800	400	65,800	--	21,500	37,600	XX	XX	--	--	122,000	--	23,800	557,000
1954	26,800	132	46,200	--	21,200	32,800	XX	XX	--	--	85,000	--	22,300	401,000
1955	25,300	260	90,800	--	34,900	26,600	XX	XX	--	--	46,100	--	28,900	595,000
1956	78,900	888	53,500	--	32,800	39,900	XX	XX	--	--	48,900	--	23,100	709,000
1957	87,200	998	79,800	--	38,600	46,500	XX	XX	--	--	64,200	--	16,400	726,000
1958	65,500	1,060	64,000	--	35,000	41,900	XX	XX	--	--	47,400	--	24,100	416,000
1959	20,700	410	95,600	--	55,000	57,700	XX	XX	--	--	44,000	--	16,300	653,000
1960	34,900	181	100,000	--	68,000	67,500	XX	XX	--	--	39,200	--	18,400	734,000
1961	31,100	100	48,700	--	73,700	70,200	XX	XX	10,500	--	36,700	--	25,500	640,000
1962	56,200	20	66,600	--	89,800	58,100	XX	XX	18,500	--	15,500	--	21,500	531,000
1963	51,200	--	69,000	--	99,800	43,700	XX	XX	11,200	--	--	--	14,500	459,000
1964	50,900	--	35,000	--	98,000	44,000	XX	XX	11,800	--	--	--	13,500	468,000
1965	50,600	--	59,700	--	129,000	41,800	XX	XX	2,380	--	--	--	14,500	555,000
1966	55,800	--	77,700	--	141,000	32,800	XX	XX	--	--	--	--	27,100	560,000
1967	12,000	--	110,000	--	109,000	45,200	XX	XX	--	--	1,240	--	26,400	420,000
1968	13,100	--	206,000	--	89,800	27,900	XX	XX	--	--	--	--	26,000	439,000
1969	24,000	--	227,000	--	150,000	30,000	XX	XX	80,000	--	--	--	23,000	469,000
1970	26,000	--	271,000	--	200,000	33,000	XX	XX	131,000	--	--	--	29,000	566,000
1971	15,000	--	261,000	--	176,000	32,000	XX	XX	150,000	--	--	--	24,000	430,000
1972	22,000	--	295,000	--	180,000	24,000	XX	XX	112,000	--	--	--	26,000	349,000
1973	18,000	--	288,000	--	140,000	24,000	XX	XX	158,000	--	--	--	17,000	581,000
1974	10,000	--	396,000	--	175,000	26,000	XX	XX	156,000	--	--	--	10,000	530,000
1975	35,000	--	500,000	--	172,000	24,000	XX	XX	194,000	--	2,000	--	10,000	520,000
1976	34,000	--	402,000	--	160,000	22,000	XX	XX	221,000	--	10,000	--	11,000	431,000
1977	42,000	--	353,000	--	233,000	18,000	XX	XX	165,000	--	8,000	--	8,000	538,000
1978	37,000	--	266,000	--	198,000	9,000	XX	XX	138,000	--	8,000	--	11,000	540,000
1979	45,000	--	310,000	--	136,000	12,000	XX	XX	128,000	--	12,000	--	3,000	556,000
1980	42,000	--	319,000	--	82,000	14,000	XX	XX	180,000	--	2,000	--	3,000	496,000
1981	24,000	--	335,000	--	32,000	11,000	XX	XX	100,000	--	5,000	--	2,000	439,000
1982	29,000	--	364,000	--	41,000	11,000	XX	XX	44,000	--	50,000	--	4,000	322,000
1983	27,000	--	360,000	--	48,000	8,000	XX	XX	45,000	--	92,000	24,000	6,000	267,000
1984	61,400	--	423,000	--	59,000	7,420	XX	XX	59,800	--	84,200	7,000	3,000	261,000
1985	58,900	--	569,000	--	56,000	11,900	XX	XX	127,000	--	78,800	--	5,190	272,000
1986	60,100	--	630,000	--	54,000	10,600	XX	XX	82,900	--	72,200	4,820	8,300	174,000
1987	63,800	--	624,000	--	92,100	11,800	XX	XX	107,000	NA	61,800	--	10,200	188,000

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Greece	Guatemala	India	Indonesia	Iran	Japan	Kazakh-stan 8/	Macedo-nia 10/	Madaga-scar 11/	Morocco	New Caledonia	Oman	Pakistan 12/	Philippines
1988	49,500	--	821,000	7,640	60,300	9,510	XX	XX	64,200	1,000	70,300	--	3,330	129,000
1989	62,300	--	1,000,000	7,640	72,600	11,700	XX	XX	62,500	1,000	60,300	12,800	27,100	217,000
1990	35,400	--	1,050,000	8,000	77,200	8,080	XX	XX	151,000	300	6,220	--	18,200	183,000
1991	37,200	--	940,000	1,950	90,100	8,000	XX	XX	149,000	500	--	--	31,500	191,000
1992	4,000	--	1,080,000	2,000	130,000	8,000	3,500,000	6,000	161,000	302	8,170	1,760	22,900	65,700
1993	10,000	--	1,000,000	2,500	124,000	7,000	2,900,000	5,000	144,000	--	--	10,200	22,200	61,700
1994	5,000	--	909,000	2,500	354,000	--	2,100,000	5,000	90,200	--	--	6,170	6,240	76,000
1995	5,000	--	1,540,000	10,000	371,000	--	2,420,000	5,000	106,000	--	--	5,300	17,000	111,000
1996	11,725	--	1,363,205	13,300 e/	130,220	--	1,190,000	5,000 e/	137,210	--	--	15,252	27,987	107,068
1997	12,020	--	1,363,049	2,156	168,984	--	1,798,300	5,000 e/	139,700	--	--	18,000	23,763	87,500
1998	12,000 e/	--	1,311,310	4,700 e/	313,937 r/	--	1,602,700	5,000 e/	104,300	--	--	28,684	8,885	53,871
1999	12,000 e/	--	1,473,000 r/	6,355	311,235 r/	--	2,405,000	5,000 e/	100,000 r/ e/	--	--	26,009 r/	16,279	19,566
2000 e/	12,000	--	1,500,000	6,400	310,000	--	2,607,000 9/	5,000	100,000	--	--	15,110 9/	26,643 9/	15,000

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Portugal	Russia 13/	Sierra Leone	South Africa 14/	Sudan	Thailand	Turkey	U.S.S.R. 15/	United Arab Emirates	United States	Vietnam 16/	Yugoslavia 17/	Zimbabwe 18/	PNRC 19/
1900	NA	XX	--	--	--	NA	9,750	19,100	--	142	NA	100	--	2,120
1901	NA	XX	--	--	--	NA	41,000	22,200	--	374	NA	505	--	1,160
1902	NA	XX	--	--	--	NA	34,600	19,700	--	320	NA	270	--	816
1903	NA	XX	--	--	--	NA	30,400	16,400	--	152	NA	147	--	3,180
1904	NA	XX	--	--	--	NA	19,200	26,600	--	125	NA	279	--	5,510
1905	NA	XX	--	--	--	NA	20,200	27,100	--	23	NA	186	--	7,780
1906	NA	XX	--	--	--	NA	32,600	19,000	--	109	NA	320	--	8,200
1907	NA	XX	--	--	--	NA	28,900	26,400	--	295	NA	164	836	6,530
1908	NA	XX	--	--	--	NA	11,500	10,900	--	365	NA	500	12,100	6,550
1909	NA	XX	--	--	--	NA	--	22,200	--	608	NA	332	23,200	2,240
1910	NA	XX	--	--	--	NA	--	14,400	--	209	NA	320	39,900	271
1911	NA	XX	--	--	--	NA	--	1,200	--	122	NA	250	47,500	142
1912	NA	XX	--	--	--	NA	--	21,300	--	204	NA	200	62,800	--
1913	NA	XX	--	--	--	NA	14,000	15,000	--	259	NA	305	57,500	--
1914	NA	XX	--	--	--	NA	9,830	15,000	--	601	NA	211	43,700	307
1915	NA	XX	--	--	--	NA	--	15,000	--	3,330	NA	370	55,000	11,500
1916	NA	XX	--	--	--	NA	--	15,000	--	47,800	NA	966	80,600	27,700
1917	NA	XX	--	--	--	NA	--	14,000	--	44,400	NA	1,810	66,200	37,300
1918	NA	XX	--	--	--	NA	1,000	14,000	--	83,800	NA	500	28,400	43,700
1919	NA	XX	--	--	--	NA	3,500	4,000	--	5,160	NA	500	32,000	13,200
1920	NA	XX	--	--	--	NA	25,000	2,770	--	2,540	NA	10	54,700	14,600
1921	NA	XX	--	1,080	--	NA	10,000	4,010	--	287	NA	10	45,500	2,540
1922	NA	XX	--	87	--	NA	2,500	847	--	361	NA	15	84,800	1,330
1923	NA	XX	--	--	--	NA	--	3,000	--	231	NA	--	87,700	3,880
1924	NA	XX	--	4,570	--	NA	3,400	11,900	--	293	NA	300	157,000	1,260
1925	NA	XX	--	13,800	--	NA	7,510	30,100	--	110	NA	12,200	123,000	895
1926	NA	XX	--	12,000	--	NA	6,670	30,400	--	143	NA	16,000	164,000	1,570
1927	NA	XX	--	17,000	--	NA	18,300	19,300	--	204	NA	8,760	198,000	2,200
1928	NA	XX	--	31,800	--	NA	11,800	29,500	--	671	NA	16,700	199,000	120
1929	NA	XX	--	64,000	--	NA	16,200	52,900	--	273	NA	43,000	266,000	234
1930	NA	XX	--	13,700	--	NA	28,200	66,700	--	81	NA	51,600	206,000	1,600
1931	NA	XX	--	23,300	--	NA	25,400	67,000	--	272	NA	58,400	81,600	2,890
1932	NA	XX	--	19,400	--	NA	55,200	65,900	--	157	NA	39,100	15,700	480
1933	NA	XX	--	34,100	--	NA	75,400	109,000	--	857	NA	26,200	35,000	2,620
1934	NA	XX	--	61,400	--	NA	120,000	127,000	--	375	NA	48,500	72,100	1,030
1935	NA	XX	--	90,400	--	NA	150,000	178,000	--	523	NA	53,000	106,000	1,370
1936	NA	XX	--	176,000	--	NA	164,000	217,000	--	273	NA	54,000	183,000	5,000
1937	NA	XX	741	169,000	--	NA	193,000	200,000	--	2,360	NA	59,900	276,000	9,690
1938	NA	XX	505	177,000	--	NA	214,000	200,000	--	825	NA	58,500	186,000	4,730
1939	NA	XX	10,800	160,000	--	NA	192,000	200,000	--	3,670	NA	59,500	139,000	9,440
1940	NA	XX	17,800	164,000	--	NA	170,000	299,000	--	2,710	NA	71,000	248,000	11,900
1941	NA	XX	13,900	142,000	--	NA	136,000	340,000	--	12,900	NA	69,900	324,000	14,800
1942	NA	XX	10,700	338,000	--	NA	116,000	399,000	--	102,000	NA	99,800	348,000	27,400
1943	NA	XX	16,300	163,000	--	NA	155,000	327,000	--	145,000	NA	65,300	287,000	48,600

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Portugal	Russia 13/	Sierra Leone	South Africa 14/	Sudan	Thailand	Turkey	U.S.S.R. 15/	United Arab Emirates	United States	Vietnam 16/	Yugoslavia 17/	Zimbabwe 18/	PNRC 19/
1944	NA	XX	9,850	88,900	--	NA	182,000	299,000	--	41,400	NA	9,980	277,000	38,200
1945	NA	XX	578	99,100	--	NA	148,000	299,000	--	12,700	NA	5,990	186,000	11,800
1946	NA	XX	10,300	212,000	--	NA	103,000	299,000	--	3,730	NA	68,000	151,000	4,320
1947	NA	XX	16,800	373,000	--	NA	157,000	499,000	--	860	NA	54,400	155,000	4,760
1948	NA	XX	7,890	413,000	--	NA	286,000	599,000	--	3,280	NA	62,600	231,000	5,090
1949	NA	XX	22,100	404,000	--	NA	452,000	349,000	--	393	NA	109,000	244,000	11,600
1950	45	XX	7,520	496,000	--	--	423,000	454,000	--	367	--	115,000	292,000	14,500
1951	33	XX	16,500	545,000	--	--	619,000	544,000	--	6,400	--	99,600	300,000	5,200
1952	108	XX	23,900	580,000	--	--	807,000	544,000	--	19,300	--	107,000	323,000	16,000
1953	5	XX	24,700	724,000	--	--	913,000	544,000	--	53,400	--	127,000	420,000	98,100
1954	21	XX	19,100	641,000	--	--	562,000	544,000	--	148,000	--	124,000	401,000	777
1955	--	XX	21,100	542,000	--	--	649,000	680,000	--	139,000	--	126,000	408,000	20,500
1956	--	XX	19,900	627,000	--	--	833,000	739,000	--	188,000	--	119,000	407,000	19,100
1957	--	XX	16,000	666,000	--	--	955,000	771,000	--	151,000	--	120,000	593,000	14,700
1958	--	XX	14,500	631,000	--	--	573,000	798,000	--	130,000	--	114,000	561,000	20,600
1959	--	XX	18,100	680,000	--	--	388,000	853,000	--	95,300	6,620	107,000	493,000	24,300
1960	--	XX	5,460	772,000	--	--	481,000	916,000	--	97,100	19,400	101,000	606,000	30,800
1961	--	XX	--	898,000	--	--	403,000	921,000	--	74,400	29,000	108,000	536,000	1,530
1962	--	XX	11,400	913,000	7,980	--	527,000	1,150,000	--	--	--	97,000	461,000	63,900
1963	--	XX	2,780	792,000	17,000	--	284,000	1,230,000	--	--	--	93,800	374,000	--
1964	--	XX	--	850,000	17,000	--	413,000	1,300,000	--	--	--	88,400	448,000	--
1965	--	XX	--	942,000	29,900	--	567,000	1,420,000	--	--	--	79,900	586,000	--
1966	--	XX	--	1,060,000	17,200	--	529,000	1,500,000	--	--	--	54,200	NA	--
1967	--	XX	--	1,150,000	25,000	--	371,000	1,570,000	--	--	--	47,200	318,000	--
1968	--	XX	--	1,150,000	22,100	--	419,000	1,650,000	--	--	--	45,300	381,000	--
1969	--	XX	--	1,197,000	25,000	--	454,000	1,700,000	--	--	--	39,000	363,000	--
1970	--	XX	--	1,427,000	47,000	--	519,000	1,751,000	--	--	--	41,000	363,000	--
1971	--	XX	--	1,644,000	21,000	--	603,000	1,796,000	--	--	--	34,000	544,000	--
1972	--	XX	--	1,483,000	23,000	--	395,000	1,851,000	--	--	--	28,000	544,000	--
1973	--	XX	--	1,649,000	32,000	--	436,000	1,905,000	--	--	--	10,000	544,000	--
1974	--	XX	--	1,877,000	20,000	--	666,000	1,950,000	--	--	NA	1,000	590,000	--
1975	--	XX	--	2,076,000	15,000	(5/)	717,000	2,077,000	--	--	NA	2,000	590,000	--
1976	--	XX	--	2,409,000	22,000	--	581,000	2,087,000	--	--	14,000	2,000	864,000	--
1977	--	XX	--	3,059,000	19,000	1,000	508,000	2,177,000	--	--	13,000	2,000	677,000	--
1978	--	XX	--	3,144,000	18,000	(5/)	381,000	3,302,000	--	--	13,000	2,000	478,000	--
1979	--	XX	--	3,297,000	28,000	(5/)	372,000	2,300,000	--	--	14,000	(5/)	542,000	--
1980	--	XX	--	3,414,000	25,000	--	373,000	2,903,000	--	--	15,000	(5/)	553,000	--
1981	--	XX	--	2,870,000	25,000	--	401,000	2,903,000	--	--	15,000	(5/)	536,000	--
1982	--	XX	--	2,431,000	19,000	--	453,000	2,939,000	--	--	16,000	--	432,000	--
1983	--	XX	--	2,466,000	20,000	--	346,000	2,939,000	--	--	16,000	--	420,000	--
1984	--	XX	--	3,410,000	20,000	--	487,000	2,940,000	--	--	16,000	--	477,000	--
1985	--	XX	--	3,700,000	8,800	30	589,000	3,360,000	--	--	4,000	10,000	536,000	--
1986	--	XX	--	3,910,000	8,500	361	618,000	3,640,000	--	--	4,000	8,780	533,000	--
1987	--	XX	--	3,790,000	13,000	5	762,000	3,570,000	--	--	4,000	13,200	570,000	--

See footnotes at end of table.

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TABLE 14--Continued
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Year	Portugal	Russia 13/	Sierra Leone	South Africa 14/	Sudan	Thailand	Turkey	U.S.S.R. 15/	United Arab Emirates	United States	Vietnam 16/	Yugoslavia 17/	Zimbabwe 18/	PNRC 19/
1988	--	XX	--	4,240,000	8,000	776	851,000	3,700,000	--	--	4,000	11,500	561,000	--
1989	--	XX	--	4,950,000	25,000	416	1,080,000	3,800,000	--	--	4,000	12,700	627,000	--
1990	--	XX	--	4,620,000	12,500	--	836,000	3,800,000	--	--	--	10,800	573,000	--
1991	--	XX	--	5,100,000	10,000	--	940,000	3,800,000	--	--	--	6,000	564,000	--
1992	--	121,000	--	3,360,000	10,000	--	759,000	XX	1,000	--	--	XX	522,000	--
1993	--	121,000	--	2,840,000	11,500	--	767,000	XX	19,000	--	--	XX	252,000	--
1994	--	143,000	--	3,640,000	25,000	--	1,270,000	XX	55,000	--	63,000	XX	517,000	--
1995	--	151,000	--	5,090,000	45,000	--	2,080,000	XX	37,000	--	25,000	XX	707,000	--
1996	--	96,700 9/	--	5,078,000	12,000 e/	--	1,279,032	XX	56,000	--	37,000	XX	697,311 9/	--
1997	--	150,000 e/	--	6,162,000	30,500 e/	--	1,702,633	XX	61,000 e/	--	51,000	XX	670,000 e/	--
1998	--	130,000 e/	--	6,480,000	20,000 e/	--	1,404,470	XX	76,886	--	54,000	XX	605,000 e/	--
1999	--	100,000 e/	--	6,817,050	10,000 e/	--	770,352	XX	60,000	--	48,300 r/	XX	654,000 r/ e/	--
2000 e/	--	100,000	--	6,620,754 9/	10,000	--	1,000,000	XX	60,000	--	55,000	XX	640,000	--

e/ Estimated. r/ Revised. NA Not available. XX Not applicable. -- Zero.

1/ Chromite ore production was reported by country starting in the 1911 Chromite Minerals Yearbook Chapter (reporting production for the years 1906 through 1910) when production was reported in metric tons. Chromite ore production by country has since been reported continually in the Chromite Minerals Yearbook chapters through 1946 and in its successor, the Chromium Minerals Yearbook chapters since 1947. In the 1958 Chromium Minerals Yearbook chapter, chromite ore production by country was reported in units of short tons for the 1900 through 1958 time period. From 1959 through 1970, chromite ore production by country was reported in short tons. From 1971 through 1987, chromite ore production by country was reported in thousand short tons. Since 1988 (1984 year-of-data), chromite ore production has been reported in metric tons. Country chromite ore production data presented here are those reported in the Minerals Yearbook chapters converted from short to metric tons where necessary and rounded to thousand tons from 1969 through 1983, and rounded to no more than three significant digits from 1900 through 1968 and from 1984 through 1995. Since unrounded data were not available before 1996, world production was computed from country production converted in units but not yet rounded; world production was then rounded to no more than three significant digits. From 1996 through 2000, chromite ore world production and estimated country production were rounded to no more than three significant digits. From 1996 through 2000 chromite ore world production and estimated country production were rounded to no more than three significant digits. Chromite ore production by country from 1900 through 1949 came from the 1958 chapter review; the remainder, from chromium chapters.

2/ Figures for all countries represent marketable output unless otherwise noted.

3/ Direct shipping plus concentrate production from 1995 through 2000.

4/ Average Cr_2O_3 content was as follows: 1996--42.2%; 1997--37.4%; 1998-99--45% (revised); and 2000--45%.

5/ Less than 500 short tons.

6/ Production estimates as exports from 1950 through 1960.

7/ Egypt reported as United Arab Republic from 1956 through 1961.

8/ Kazakhstan formerly part of the U.S.S.R. from 1900 through 1991.

9/ Reported figure.

10/ Macedonia reported as Yugoslavia from 1900 through April 1992.

11/ Madagascar reported as Malagasy or Malagasy Republic from 1950 through 1974.

12/ Pakistan reported with India from 1900 through 1946.

13/ Russia reported as the U.S.S.R. from 1900 through 1991.

14/ South Africa reported as the Union of South Africa from 1900 through 1957.

15/ The U.S.S.R. dissolved in December 1991.

16/ Reported as North Vietnam from 1959 through 1961.

17/ Yugoslavia part of Austria-Hungary from 1900 through 1917; Kingdom of the Serbs, Croats and Slovenes from 1918 through 1928. Dissolved in April 1992.

18/ Zimbabwe reported as Southern Rhodesia from 1900 through 1950 and 1960 through 1975, and as Federation of Rhodesia and Nyasaland from 1951 through 1959.

19/ Production not reported by country includes data from Afghanistan, Argentina, Brazil, Bulgaria, Canada, Guatemala, Indochina, Lebanon, Mexico, Norway, Portugal, Romania, Sweden, and the United Kingdom from 1900 through 1949; Bulgaria and Romania from 1950 through 1962; and North Vietnam for 1962.

Source: U.S. Geological Survey and U.S. Bureau of Mines publications, including Mineral Resources of the United States, Minerals Yearbooks, Commodity Data Summaries, and Mineral Commodity Summaries.

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TABLE 15
FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/

(Metric tons, gross weight)

Year	World total	Albania	Australia	Brazil	Chile	China	Croatia 2/
1974	1,855,000	--	4,000	38,000	--	--	XX
1975	1,695,000	--	4,000	53,000	--	--	XX
1976	2,136,000	--	--	60,000	--	59,000	XX
1977	2,419,000	--	--	66,000	--	73,000	XX
1978	2,649,000	--	--	63,000	--	91,000	XX
1979	2,996,000	NA	--	84,000	--	91,000	XX
1980	2,858,000	4,000	--	93,000	--	118,000	XX
1981	2,649,000	28,000	--	119,000	--	118,000	XX
1982	2,306,000	30,000	--	97,000	--	118,000	XX
1983	2,370,000	35,000	--	77,000	--	118,000	XX
1984	2,830,000	40,000	--	125,000	--	118,000	XX
1985	2,974,000	43,000	--	127,000	--	122,000	XX
1986	3,210,000	46,000	--	109,000	--	--	XX
1987	3,310,000	26,300	--	105,000	475	NA	XX
1988	3,800,000	33,700	--	130,000	2,210	NA	XX
1989	3,890,000	38,800	--	113,000	2,840	180,000	XX
1990	3,760,000	24,000	--	83,800	1,870	340,000	XX
1991	3,880,000	25,000	--	82,200	2,510	380,000	XX
1992	3,620,000	21,700	--	91,100	2,110	410,000	56,500
1993	3,270,000	35,600	--	83,900	680	372,000	27,300
1994	3,700,000	33,800	--	77,100	1,580	370,000	31,700
1995	4,710,000	43,000	--	101,000	2,730	500,000	26,100
1996	3,950,000	31,189	--	77,231 3/	2,079	423,000 e/	10,559
1997	4,830,000 r/	31,144 r/	--	74,485 r/ 3/	-- r/	480,000 e/	24,231
1998	4,750,000 r/	30,252 r/	--	72,507 r/ 3/	-- r/	424,000 e/	11,770
1999	4,930,000 r/	28,120 r/	--	90,784 r/ 3/	-- r/	400,000 e/	-- r/
2000 e/	5,130,000	9,900	--	91,000 3/	--	450,000	15,753 4/

Year	Czecho-slovakia 5/	Finland	France	Germany 6/	Greece	India	Iran
1974	(7/)	48,000	112,000	(7/)	--	15,000	--
1975	(7/)	40,000	56,000	(7/)	--	10,000	--
1976	30,000	40,000	102,000	89,000	--	17,000	--
1977	30,000	34,000	102,000	79,000	--	18,000	--
1978	30,000	44,000	93,000	75,000	--	22,000	--
1979	28,000	49,000	95,000	81,000	--	22,000	--
1980	27,000	53,000	44,000	77,000	--	16,000	--
1981	27,000	52,000	27,000	70,000	--	32,000	--
1982	25,000	54,000	38,000	62,000	--	42,000	--
1983	25,000	59,000	20,000	57,000	18,000	35,000	--
1984	24,000	59,000	19,000	64,000	33,000	55,000	--
1985	25,000	133,000	1,000	69,000	34,000	66,000	--
1986	28,200	134,000	1,000	82,000	38,300	84,100	--
1987	29,000	143,000	1,000	71,000	49,000	126,000	--
1988	29,200	156,000	13,200	56,900	44,100	140,000	--
1989	29,800	169,000	18,100	55,400	43,600	151,000	--
1990	37,500	157,000	25,000	58,500	30,300	169,000	--
1991	41,200	190,000	23,100	38,300	10,500	229,000	--
1992	52,500	187,000	6,690	26,500	--	193,000	--
1993	XX	218,000	--	16,400	--	228,000	--
1994	XX	254,000	--	17,300	--	251,000	7,150
1995	XX	247,000	--	21,700	--	304,000	11,900
1996	XX	227,811	--	25,303	--	261,666 8/	10,500
1997	XX	236,652	--	25,856	--	286,973 8/	11,450
1998	XX	230,906	--	20,879	--	345,125 8/	13,745
1999	XX	256,290 r/	--	16,960	--	350,000 e/ 8/	13,680 r/
2000 e/	XX	260,600 6/	--	17,000	--	352,000 8/	14,000

See footnotes at end of table.

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TABLE 15--Continued
FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/

(Metric tons, gross weight)

Year	Italy	Japan	Kazakh-stan 9/	Mace-donia 2/	Mexico	Norway	Philippines
1974	40,000	542,000	XX	XX	--	31,000	--
1975	44,000	486,000	XX	XX	--	27,000	--
1976	45,000	464,000	XX	XX	4,000	32,000	--
1977	40,000	399,000	XX	XX	3,000	23,000	--
1978	37,000	274,000	XX	XX	5,000	15,000	10,000
1979	43,000	366,000	XX	XX	5,000	12,000	10,000
1980	41,000	403,000	XX	XX	--	11,000	10,000
1981	10,000	306,000	XX	XX	3,000	12,000	10,000
1982	36,000	328,000	XX	XX	6,000	10,000	12,000
1983	12,000	298,000	XX	XX	3,000	4,000	27,000
1984	13,000	318,000	XX	XX	7,000	4,000	48,000
1985	58,000	340,000	XX	XX	6,000	--	51,000
1986	55,900	281,000	XX	XX	2,670	--	55,000
1987	59,000	264,000	XX	XX	6,300	--	47,000
1988	87,100	295,000	XX	XX	9,300	--	73,000
1989	87,300	334,000	XX	XX	2,570	--	82,000
1990	53,000	304,000	XX	XX	275	60,000	55,700
1991	47,200	279,000	XX	XX	72	83,000	23,700
1992	60,300	276,000	400,000	3,960	70	102,000	27,400
1993	53,500	211,000	328,000	4,380	--	80,000	11,900
1994	22,700	193,000	373,000	3,160	--	120,000	16,200
1995	51,000	210,000	512,000	3,770	--	148,000	50,500
1996	29,915	193,695 3/	352,000	3,780	--	108,900	6,736
1997	11,295	186,432 3/	600,000	460	--	145,124	--
1998	11,487	142,931 3/	535,000	--	--	174,678	--
1999	12,000 e/	119,777 3/	597,946	--	--	159,714	--
2000 e/	12,000	130,074 3/ 4/	640,000	--	--	165,000	--

Year	Poland	Romania	Russia 9/	Slovakia 10/	Slovenia 10/	South Africa	Southern Rhodesia 11/
1974	(7/)	--	XX	XX	XX	184,000	181,000
1975	(7/)	--	XX	XX	XX	217,000	200,000
1976	50,000	--	XX	XX	XX	350,000	186,000
1977	50,000	--	XX	XX	XX	350,000	XX
1978	47,000	--	XX	XX	XX	660,000	XX
1979	49,000	--	XX	XX	XX	780,000	XX
1980	47,000	34,000	XX	XX	XX	800,000	XX
1981	41,000	36,000	XX	XX	XX	753,000	XX
1982	35,000	39,000	XX	XX	XX	472,000	XX
1983	48,000	42,000	XX	XX	XX	675,000	XX
1984	48,000	45,000	XX	XX	XX	867,000	XX
1985	49,000	44,000	XX	XX	XX	852,000	XX
1986	36,200	44,000	XX	XX	XX	870,000	XX
1987	35,900	42,000	XX	XX	XX	965,000	XX
1988	36,300	23,400	XX	XX	XX	994,000	XX
1989	28,200	26,800	XX	XX	XX	1,050,000	XX
1990	13,700	20,600	XX	XX	XX	1,020,000	XX
1991	1,930	20,400	XX	XX	XX	1,150,000	XX
1992	35,300	6,970	400,000	XX	17,100	771,000	XX
1993	38,400	3,910	256,000	50,600	8,810	834,000	XX
1994	7,350	3,890	266,000	48,600	13,400	1,100,000	XX
1995	18,300	15,100	290,000	65,300	23,200	1,520,000	XX
1996	1,100 r/	9,650	135,000 e/	19,900	22,819	1,478,000 12/	XX
1997	6,200 r/	950	247,000 e/	11,394	9,232	1,939,500 12/	XX
1998	4,200 r/	873	203,000	11,715	10,621	2,025,300 12/	XX
1999	3,500 e/	--	249,000	6,986	560	2,155,202 r/ 12/	XX
2000 e/	3,500	--	274,000	7,000	600	2,200,000 12/	XX

See footnotes at end of table.

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TABLE 15--Continued
FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/

(Metric tons, gross weight)

Year	Spain	Sweden	Turkey	U.S.S.R. 13/	United States	Yugo-slavia 14/	Zim-babwe 11/
1974	22,000	101,000	9,000	184,000	306,000	39,000	XX
1975	18,000	93,000	9,000	206,000	179,000	54,000	XX
1976	20,000	116,000	25,000	210,000	195,000	43,000	XX
1977	16,000	134,000	35,000	535,000	197,000	36,000	200,000
1978	14,000	166,000	40,000	553,000	160,000	51,000	200,000
1979	20,000	190,000	30,000	553,000	224,000	65,000	200,000
1980	16,000	144,000	32,000	390,000	167,000	69,000	260,000
1981	17,000	146,000	41,000	400,000	149,000	69,000	184,000
1982	15,000	117,000	40,000	415,000	83,000	51,000	180,000
1983	14,000	120,000	30,000	415,000	18,000	64,000	158,000
1984	14,000	134,000	48,000	420,000	86,000	63,000	178,000
1985	17,000	135,000	50,000	420,000	100,000	73,000	156,000
1986	14,000	126,000	50,000	798,000	95,600	68,600	187,000
1987	16,000	112,000	52,500	806,000	107,000	56,300	187,000
1988	25,400	143,000	54,000	1,050,000	120,000	93,300	190,000
1989	29,000	154,000	59,700	828,000	147,000	90,400	173,000
1990	15,000	118,000	62,000	700,000	109,000	82,700	222,000
1991	6,000	121,000	84,700	700,000	68,300	91,000	187,000
1992	--	133,000	85,800	XX	60,900	--	191,000
1993	2,390	128,000	90,000	XX	63,000	--	124,000
1994	2,300	134,000	97,600	XX	67,400	--	183,000
1995	1,320	130,000	94,300	XX	72,500	--	254,000
1996	805	138,110	101,450	XX	36,800 15/	--	243,000
1997	490	101,842	108,320	XX	60,700 15/	--	233,386
1998	1,145	123,958	110,175	XX	W 15/	--	246,782
1999	935	113,140	110,000 e/	XX	W 15/	--	244,379 r/
2000 e/	1,000	135,000	110,000	XX	W 15/	--	246,324 4/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable. -- Zero.

1/ Ferrochromium production was reported by country starting in the 1976 Ferroalloys Minerals Yearbook Chapter (data series starting in 1974) as part of the world ferroalloy production table. Ferrochromium production was reported in units of thousand short tons from the 1976 chapter through the 1989 chapter. In the 1990 Ferroalloys Minerals Yearbook Chapter (1986 data), reporting units changed to metric tons. Ferrochromium production by country was added to the Chromium Minerals Yearbook Chapter in 1988 where production was reported for 1988 as thousand metric tons. Reporting ferrochromium production by country in the Chromium chapter lapsed for 2 years after which it was reintroduced in 1991 as a 5-year table (first year-of-data 1987) in units of metric tons. Ferrochromium production by country has since been reported in the Chromium chapter. In 1994, a policy of rounding data to no more than three significant digits was implemented. The policy applies to published data such as production for a specific country for a specific year. Information computed from that data, such as world production, is to be computed from unrounded data. Country ferrochromium production data presented here is that reported in the Minerals Yearbook Chapters converted from short to metric tons where necessary and rounded to thousand metric tons from 1974 through 1985 and rounded to no more than three significant digits from 1986 through 1995. Since unrounded data were not available before 1996, world production was computed from country production converted in units but not yet rounded; world production was then rounded to no more than three significant digits. From 1996 through 2000 ferrochromium world production, U.S. production, and estimated country production were rounded to no more than three significant digits.

2/ Croatia and Macedonia reported as part of Yugoslavia from 1974 through 1991.

3/ Includes high- and low-carbon ferrochromium.

4/ Reported figure.

5/ Czechoslovakia dissolved on December 31, 1992.

6/ Reported as East and West or Democratic and Federal Republic of Germany from 1974 through 1990.

7/ Undistributed.

8/ Includes ferrochrome and charge chrome.

9/ Kazakhstan and Russia reported as part of the U.S.S.R. from 1974 through 1991.

10/ Slovakia reported as part of Czechoslovakia from 1974 through 1992; Slovenia reported as part of Czechoslovakia from 1974 through 1991.

11/ Zimbabwe reported as Southern Rhodesia from 1974 through 1976.

12/ Includes high- and low-carbon ferrochromium and ferrochromium silicon.

13/ The U.S.S.R. disolved in December 1991.

14/ Yugoslavia dissolved in April 1992.

15/ Includes high- and low-carbon ferrochromium, ferrochromium silicon, chromium metal, and other chromium materials.

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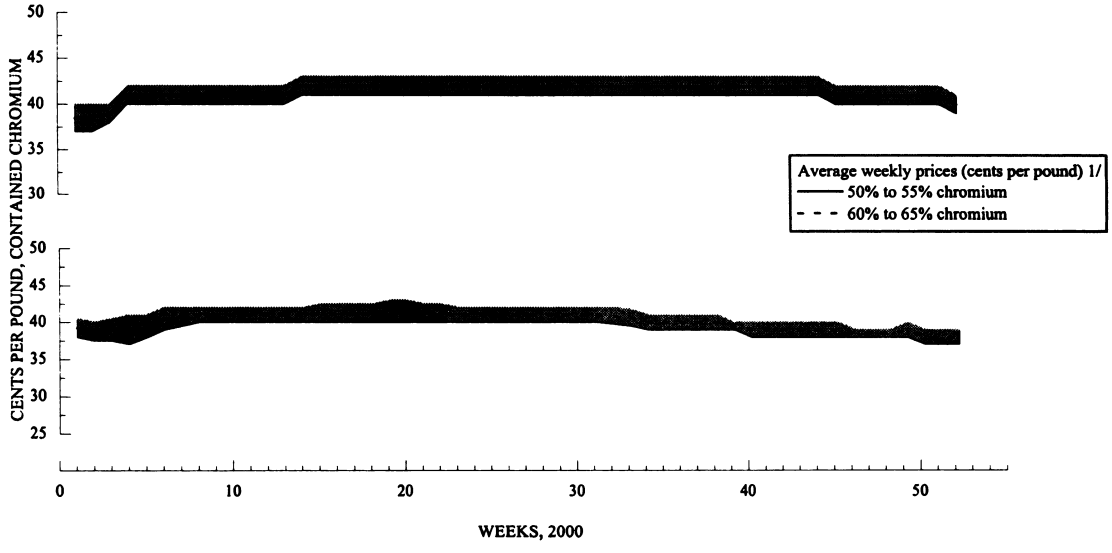
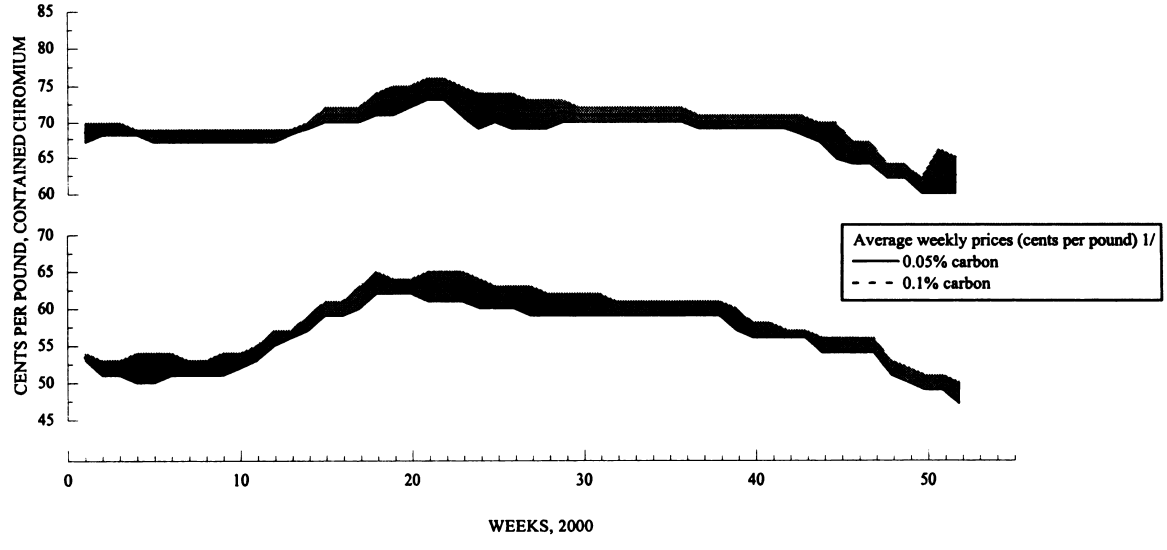
FIGURE 1
U.S. IMPORTED HIGH-CARBON FERROCHROMIUM IN 2000



1/ Average weekly price shown against price range background.
Source: Platt's Metals Week

FIGURE 2
U.S. IMPORTED LOW-CARBON FERROCHROMIUM IN 2000



1/ Average weekly price shown against price range background.
Source: Platt's Metals Week

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CLAYS

By Robert L. Virta

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

The amount of clay sold or used by domestic producers in 2000 was 40.8 million metric tons (Mt) valued at $1.52 billion, a decrease of 3% in tonnage and value from that of 1999. Production of fire clay and fuller's earth increased, but production of ball clay, bentonite, common clay and shale, and kaolin decreased. Of the clay and shale produced in 2000, common clay and shale accounted for 58% of the tonnage, and kaolin accounted for 61% of the value. Imports of clays increased to 95,500 metric tons (t) valued at $34.9 million. Exports increased to 5.26 Mt valued at $896 million (table 1).

Legislation and Government Programs

The U.S. Environmental Protection Agency continued its work on the maximum achievable control technology (MACT) emission standards for the clay processing and manufacturing industries. The MACT standards are required under the National Emissions Standards for Hazardous Air Pollutants Program, which was established by the 1990 Amendments to the Clean Air Act. The MACT standards cover clay processors and manufacturers of lightweight aggregate, brick and structural clay products, and ceramics. The agency will issue MACT standards for each category because each has different emissions, emission controls, and economic considerations (American Ceramic Society Bulletin, 2000).

The U.S. Food and Drug Administration (FDA) clarified its guidance document for dioxins in anticaking agents, including clay, used in animal feeds. At issue was the use of the terms "mined clay products" and "lime" in the guidance document. In the first case, nonclay anticaking agents also were covered. In the later, limestone rather than lime was covered. The wording was changed to "clay and nonclay anticaking agents" to avoid any confusion, and the FDA urged the animal feed industry to develop a more scientifically accurate naming scheme for its products to avoid confusion in the future (U.S. Food and Drug Administration, 2000).

Clay mining has an environmental impact because of the disturbance to the land. Overburden is moved, and clays are removed, leaving a depression or pit. State laws usually require leveling or contouring of the disturbed area and planting trees or grasses to prevent or minimize erosion. For processing, the impoundment of slimes and dust control are usually required. The rules for disposal of coarse tailings are similar to or included within those laws governing reclamation of the mined area.

Production

In 2000, 228 companies operated approximately 640 clay and shale pits or quarries. The largest 20 companies, many with multiple operations, accounted for 50% of the tonnage and 79% of the value for all types of clay produced and sold or used. Clay production was reported in all States except Alaska, Delaware, Hawaii, Idaho, New Hampshire, Rhode Island,

Clay and Shale in the 20th Century

By 1900, the domestic clay and shale industry was fairly well established. Production of all clay types was about 1.1 million metric tons per year; fire clay accounted for 69% of the clay and shale produced in the United States, followed by common and miscellaneous clays, 18%; stoneware clay, 9%; kaolin, 2%; ball clay, 1%; and fuller's earth, 1%. In the early 1900s, the major clay markets were fire brick and refractory mortars. Other large markets included brick, drain tile, sewer tile, and structural tile for both fire clay and common clay. Markets for the other clay types were much smaller. Major uses for ball clay were in ceramics. The major market for bentonite was foundry sand bond. Decolorizing oils and greases applications were major applications for bentonite and fuller's earth. Paper and ceramics were the major markets for kaolin. Fire clay production continued to dominate until the 1940s when it was surpassed by common clay and shale. Despite this, the time period between 1945 and 1970 were the boom years for fire clay. In contrast to the production of common clay and shale and fire clay, production of ball clay, bentonite, fuller's earth, and kaolin increased at a relatively steady pace from 1900 onward.

In 2000, domestic production of clays was 40.7 million tons. Common clay and shale accounted for 58% of production, followed by kaolin, 22%; bentonite, 9%; fuller's earth, 7%; ball clay, 3%; and fire clay, 1%. Major uses for ball clay in 2000 were ceramic tile (35%) and sanitaryware (22%); foundry sand bond (28%), pet waste absorbent (23%), drilling mud (17%), and iron ore pelletizing (13%) for bentonite; brick (56%), cement (17%), and lightweight aggregate (16%) for common clay and shale; refractories (73%) for fire clay; absorbents (75%) for fuller's earth; and paper (61%) and refractories (11%) for kaolin. In general, variations in sales of clay and shale tracked the rise and fall of the U.S. economy because much of the clay tonnage was associated with construction. A few specific factors that affected sales of clay and shale were increased oil drilling in the 1920s and its decline in the late 1980s, the Great Depression of the 1930s, changes in refractory demands beginning in the 1960s, decreased use of brick in housing beginning in the late 1970s, the energy crisis of the 1970s, and the popularity of clumping pet waste absorbents and the intrusion of precipitated calcium carbonate into the domestic paper market in the 1990s.

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Vermont, Wisconsin, and the District of Columbia (table 2). For States not reporting production, clay probably was extracted for construction uses by companies not participating in the U.S. Geological Survey (USGS) canvass of the clay and shale industry.

The 10 leading producer States, in decreasing order by tonnage, were Georgia, Wyoming, Alabama, Texas, North Carolina, Missouri, Ohio, South Carolina, California, and Virginia. The 10 leading producing companies, in alphabetical order, were American Colloid Co. (bentonite); Engelhard Corp. (fuller's earth and kaolin); General Shale Products Corp. (common clay and shale); Glen Gery Corp. (common clay and shale); Holnam, Inc. (common clay and shale); J.M. Huber Corp. (kaolin) IMERYS (kaolin); Oil-Dri Corp. (fuller's earth); Radex Heraklith Industriesbeteilgungs AG (fire clay and kaolin); and Thiele Kaolin Co. (kaolin).

Most clay mining in the United States was by open pit methods; less than 1% of U.S. clay output was from underground mines. All the underground production was in Ohio, where the clays are mainly underclays associated with coal.

Domestic production data for clays were developed by the USGS from a voluntary survey of U.S. operations. Responses to the survey (354 of 544 sent) account for approximately 85% of the total clay and shale production sold or used listed in table 1. The bulk of the nonrespondents were producers of common clay and shale. Production data for the nonrespondents were estimated from reported prior-year production levels adjusted for trends in the industry and other guidelines.

Ball Clay.—In 2000, 4 companies mined ball clay from 38 quarries in 4 States. Production of domestic ball clay decreased to 1.14 Mt valued at $48.4 million in 2000 from 1.20 Mt valued at $48.0 million in 1999 (table 3). Tennessee supplied 60% of the Nation's output, followed by Texas, Kentucky, and Mississippi. Production increased in Mississippi and decreased in Kentucky, Tennessee, and Texas. Water-slurried ball clay was produced in Kentucky and Tennessee. Airfloat and shredded (unprocessed) ball clay was produced in Kentucky, Mississippi, Tennessee, and Texas.

Hecla Mining Co. sold its subsidiary Kentucky-Tennessee Clay Co. (K-T Clay) to the French investment group IMERYS. K-T Clay is the largest domestic producer of ball clay. The sale consisted of K-T Clay's ball clay operations in Kentucky, Mississippi, and Tennessee and its kaolin operations in Georgia and South Carolina. IMERYS also operates kaolin mines in Georgia (North American Minerals News, 2000b; Hecla Mining Co., 2001).

Unimin Corp. completed its acquisition of United Clays Inc., a division of Watts Blake Bearne & Co. plc (WBB). Unimin also is linked to WBB through its parent corporation SCR Sibelco SA, which has 100% ownership of WBB (North American Minerals News, 2000f).

Bentonite.—In 2000, 20 companies produced bentonite from approximately 82 pits in 11 States. The quantity and value of all varieties of bentonite sold or used decreased to 3.76 Mt valued at $155 million in 2000 from 4.07 Mt valued at $176 million in 1999 (table 5). Production of nonswelling bentonite increased to 400,000 t valued at $14.0 million in 2000 from 392,000 t valued at $13.2 million in 1999. Alabama led all States in the production of nonswelling bentonite, followed by Mississippi, Arizona, Texas, Nevada, California, and Colorado. Production increased in Colorado, Mississippi, and Nevada.

Production of swelling bentonite decreased to 3.36 Mt valued at $141 million in 2000 from 3.68 Mt valued at $163 million in 1999. Wyoming led all States in the production of swelling bentonite, followed by Montana, Utah, California, Texas, Oregon, and Nevada. Production increased in Nevada.

Laporte plc sold its subsidiary Southern Clay Products, Inc. (SCP), to Kohlberg, Kravis, Roberts & Co. LP for $1.18 billion. SCP sold bentonite, hectorite, and organoclay-based products for markets such as oil drilling fluids, cosmetics, and pharmaceuticals (North American Minerals News, 2000d). SCP also commissioned a specialty-products processing unit at its plant in Texas. The unit will produce smectite-based functional additives, including organoclays, nanoclays, and rheological additives (Southern Clay Products, Inc., 2000c). SCP also was awarded damages against Sud-Chemie, Inc., for patent infringement involving two of SCP's organoclay patents (Southern Clay Products, Inc., 2000d).

American Colloid began construction of a blending plant in Butler, GA. This will be the company's 10th blending plant in the United States and the 3d in Georgia. The plant will produce custom bentonite-based binders for foundry metal casting. The company also is diversifying its pet litter lineup through its agreement with The Andersons Inc. to distribute Andersons' corn-cob based litter. American Colloid already markets its clay-based scoopable pet litters (North American Minerals News, 2000a).

Common Clay and Shale.—In 2000, 175 companies produced common clay and shale from approximately 360 pits in 41 States and Puerto Rico. For States not reporting production, common clay and shale probably was mined and sold for construction uses by companies not participating in the USGS canvass of the clay and shale industry. Most companies were manufacturers of structural clay products, such as brick, clay pipe, drain tile, and sewer pipe; lightweight aggregates; and cement. About 89% of the production was used to manufacture brick, lightweight aggregate, and cement.

Domestic sales or use of common clay and shale decreased to 23.7 Mt valued at $135 million in 2000 from 24.8 Mt valued at $155 million in 1999 (table 7). The major producing States, in decreasing order by tonnage, were North Carolina, Texas, Alabama, Georgia, Ohio, Missouri, Virginia, Kentucky, California, and Arkansas.

Fire Clay.—Fire clay producers were mostly refractories manufacturers that used the clays in firebrick and other refractories. In 2000, 42 pits were operated by 12 firms in 6 States.

Fire clay sold or used by domestic producers increased to 476,000 t valued at $7.56 million in 2000 from 402,000 t valued at $6.77 million in 1999 (table 9). Missouri was the leading producing State, followed by Ohio, South Carolina, California, Colorado, and Kentucky. Production increased in California, Colorado, Missouri, and South Carolina.

Fuller's Earth.—In 2000, 17 companies produced fuller's earth (attapulgite and montmorillonite varieties) from 29 pits in 11 States. Production of fuller's earth increased to 2.91 Mt valued at $254 million in 2000 from 2.56 Mt valued at $231 million in 1999 (table 11; discussion under "Prices"). The fuller's earth deposits grade from attapulgite-rich in Florida to montmorillonite-rich further northward into Georgia. Only those clays for which attapulgite is the major clay component are classified as attapulgite. These basically are the gellant-grade fuller's earths in Florida and the southernmost part of

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Georgia. Going northward into Georgia, the attapulgite content of the fuller's earth declines, and montmorillonite becomes the dominant clay present. This is classified under montmorillonite although it contains minor to trace amounts of attapulgite.

The attapulgite variety of fuller's earth was mined from eight pits in the Florida panhandle and southwestern Georgia. Attapulgite production was estimated to be 292,000 t in 2000, an increase from 289,000 t in 1999. Florida led in the production of attapulgite, followed by Georgia. Production of the montmorillonite variety of fuller's earth was 2.62 Mt in 2000, an increase from 2.28 Mt in 1999. Montmorillonite was produced, in decreasing order by tonnage, in Georgia, Mississippi, Illinois, Missouri, Virginia, California, Florida, Tennessee, Kansas, and Texas.

Sepiolite clay produced in Nevada is included under the attapulgite variety of fuller's earth to protect proprietary information. Production in Kansas is a saprolitic clay but is included under montmorillonite to protect proprietary information.

Kaolin.—In 2000, 22 firms mined kaolin from approximately 93 pits in 10 States. Domestic production decreased to 8.80 Mt valued at $929 million in 2000 from 9.16 Mt valued at $948 million in 1999 (table 13). The leading producing State was Georgia, followed by Alabama, South Carolina, California, Texas, North Carolina, Nevada, Florida, Arkansas, and Tennessee.

Approximately 55% of the kaolin produced was water washed; 16%, airfloat; 14%, calcined; 13%, delaminated; and 2%, unprocessed (table 14). A total of 1.19 Mt valued at $261 million of calcined kaolin was reported. Of this amount, 839,000 t valued at $247 million was pigment-grade (low-temperature). The remainder was refractory-grade (high-temperature) calcined kaolin (table 15). It is believed that refractory-grade calcined kaolin production was greatly underreported by producers in 2000. Actual U.S. production is estimated to be about 1.0 Mt rather than the 354,000 t reported by producers, based on past mining trends and economic conditions.

Kaolin production in Georgia decreased to 7.66 Mt valued at $877 million in 2000 from 8.16 Mt valued at $907 million in 1999. Approximately 62% of the production was sold as water washed; 11%, pigment-grade calcined; 15%, delaminated; 8%, airfloat; and 4%, refractory-grade calcined and unprocessed (table 16). Production of calcined kaolin in Georgia probably was about 1.4 Mt in 2000 rather than 1.07 Mt due to underreporting by refractory producers. Production in South Carolina decreased to 397,000 t valued at $21.9 million in 2000 from 408,000 t valued at $15.7 million in 1999. Approximately 85% of the production was airfloat kaolin, with the remainder being unprocessed (table 18).

Unimin Corp. began negotiations with Süd-Chemie Inc. for the purchase of Albion Kaolin Co. Albion Kaolin was owned by United Catalysts Inc., a subsidiary of Süd-Chemie Inc. Albion Kaolin is the largest producer of airfloat kaolin with plants in McIntrye and Hephzibah, GA. Its main market segment is fiberglass (48% of sales). Other markets were in adhesives, building materials, ceramics, paper, and rubber. Unimin also produces bentonite, feldspar, limestone, mica, nepheline syenite, olivine, quartz (high purity), silica sand, and tripoli (Industrial Minerals, 2000h).

C-E Minerals Inc., part of the French investment group IMERYS, bought North American Processing Co. (NAPCO) from Allied Mineral Products Inc. and Frank & Schulte GmbH. NAPCO has a 70,000-metric-ton-per-year (t/yr) plant in Newell, WV, for processing bauxite, fused alumina, magnesite, magnesia, silicon carbide, and toll processing for other users of refractory materials. C-E Minerals operates facilities in Andersonville, GA, processing kaolin for its alumina silica calcine products (Industrial Minerals, 2000b).

Sparta Kaolin Corp, a subsidiary of Kaoclay Resources Inc., completed its exploration program in east-central Georgia, within 40 kilometers of existing kaolin operations. The company estimates that its deposits contain 43 Mt of kaolin resources. About 35 Mt of this amount has a brightness of 90.9%. The company has about 53 Mt of inferred resources that it is currently investigating. Kaoclay Resources does not intend to enter into the mining industry but is seeking partners to develop the deposit (Industrial Minerals, 2000d).

Thiele Kaolin Co. announced talks with Companhia Vale do Rio Doce (CVRD) in Brazil to be their exclusive marketing agent for paper coating kaolins produced by Para Pigmentos SA (PPSA). PPSA operates a 600,000 t/yr plant in Para, Brazil. It sells its paper coating products mainly to Brazil, Europe, Japan, and other Southeast Asian countries. Thiele Kaolin also is trying to acquire a minority percentage of CVRD's controlling interest in PPSA (North American Minerals News, 2000e).

Consumption

Ball Clay.—The principal domestic ball clay markets, in decreasing order, were floor and wall tile, sanitaryware, and refractories (table 4). Consumption decreased to 1.14 Mt in 2000 from 1.20 Mt in 1999. The largest increase in sales was in miscellaneous ceramics, where sales for electrical porcelain, fiber glass, fine china and dinnerware, and mineral wool increased. Sales for floor tile, refractories, and wall tile applications also increased. Decreases were observed in sales for pottery and sanitaryware. Under miscellaneous sales, sales for waterproofing and sealing applications increased, and sales for brick and drilling mud declined significantly. In general, sales and use of ball clay had increased in recent years because growth in commercial and residential building construction and home renovations has increased demand for sanitaryware, tile, and whiteware. The slight decline in the housing market affected sales in 2000.

Bentonite.—Major markets for bentonite were drilling mud, foundry sand, iron ore pelletizing, and pet waste absorbents. These markets accounted for about 85% of the domestic sales (table 6). Total sales (domestic and exports) of bentonite were approximately 710,000 t for drilling mud (more than 99% was swelling bentonite), 1.07 Mt for foundry sand bond (833,000 t was swelling bentonite), 558,000 t for pelletizing iron ore (all swelling bentonite), 865,000 t for pet waste absorbent (more than 99% was swelling bentonite), and 285,000 t for waterproofing and sealing (more than 99% was swelling bentonite). These five markets accounted for 93% of total bentonite sales.

Data for other bentonite markets were withheld to avoid disclosing company proprietary data. However, more than 90% of the bentonite sold for absorbents, adhesive, animal feed, drilling, pelletizing iron ore, waterproofing, and water treatment and slightly more than 78% of bentonite sold for foundry sand applications was swelling bentonite. Bentonite sold for catalyst; desiccant; filtering, clarifying, and decolorizing of oils and

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greases; and paint, pharmaceutical, and miscellaneous chemical manufacture applications was largely the nonswelling variety of bentonite.

The major domestic markets for swelling bentonite, in decreasing order, were pet waste absorbents, foundry sand, drilling mud, iron ore pelletizing, and waterproofing and sealing. Major export markets for swelling bentonite were foundry sand, drilling mud, and iron ore pelletizing applications. The major domestic uses for nonswelling bentonite, in decreasing order, were in clarifying, decolorizing, and filtering of oils and greases; foundry sand; catalyst; miscellaneous absorbents; animal feed; and chemical manufacture. Very little nonswelling bentonite was exported.

Common Clay and Shale.—Common clay was used most frequently in the manufacture of heavy clay products, such as building brick, drain tile, flue linings, lightweight aggregate, portland cement, sewer pipe, structural tile, and terra cotta (table 8). Consumption of common clay and shale decreased slightly to 23.7 Mt in 2000 from 24.8 Mt in 1999. The strong housing and commercial building market has helped maintain sales of common clay and shale for brick and lightweight aggregate manufacture for the past several years, but the industry was affected by a slight decline in housing starts in 2000.

Fire Clay.—Fire clay was used in refractory products, such as firebrick and block, grogs and calcines, high-alumina brick and specialties, saggers, refractory mortars and mixes, and ramming and gunning mixes. Fire clays also were used to produce such items as brick and pottery.

Consumption of fire clay increased to 476,000 t in 2000 from 402,000 t in 1999 (table 10). Major markets for fire clay, in decreasing order, were firebrick, refractory mortar and cement, portland cement, miscellaneous refractories, grogs and calcines, quarry tile, pottery, and common brick. Portland cement manufacture accounted for most of the increase in sales under heavy clay products and lightweight aggregates.

Fuller's Earth.—The major domestic uses for attapulgite and montmorillonite varieties of fuller's earth, in decreasing order, were pet waste absorbents; oil and grease absorbents; portland cement manufacture; animal feed; pesticide carrier; filtering, clarifying, and decolorizing of oils and greases; fertilizer carriers; cement manufacture; and pesticide carriers (table 12). Consumption of fuller's earth increased to 2.91 Mt in 2000 from 2.56 Mt in 1999.

Sales of montmorillonite increased to 2.62 Mt in 2000 from 2.28 Mt in 1999. Major domestic markets for montmorillonite, in decreasing order, were pet waste absorbents; oil and grease absorbents; portland cement; animal feed; clarifying, decolorizing, and filtering of oils and greases; and pesticide carrier.

Sales of attapulgite increased to 292,000 t in 2000 from 289,000 t in 1999. Most of the sales data were withheld to avoid disclosing company proprietary data; major markets, in decreasing order, were oil and grease absorbents; drilling mud; fertilizer carriers; paint; pet waste absorbents; adhesives; pesticide carriers; and animal feed.

Sales of montmorillonite variety of fuller's earth accounted for more than 70% of sales of fuller's earth for animal feed; clarifying, decolorizing, and filtering oils and greases; desiccant; oil and grease absorbents; pesticide carriers; and pet waste absorbents. Attapulgite accounted for more than 75% of the sales for adhesive and fertilizer carriers and all of the sales for asphalt tile, drilling mud, gypsum products, paint, pharmaceuticals, roofing granules, and textiles.

Kaolin.—The major domestic markets for kaolin, in decreasing order, were paper coating and filler, refractories (although reported as 425,000 t in 2000 by producers, sales are believed to be closer to 1.0 Mt), paint, fiber glass, rubber, catalyst, and brick (table 20). The largest increase in sales was for paint, which increased by 13% or 38,000 t in 2000. The largest decreases were in paper coating (180,000 t or 6%) and paper fillers (281,000 t or 36%). Both have been affected in recent years by competition from calcium carbonate and a lackluster paper market. Sales of kaolin for refractories were reported to be about 425,000 t in 2000 or about 55% of sales in 1999. Underreporting by refractory producers is believed to have occurred, and refractory sales probably have been about 1.0 Mt for the past 2 years, with 2000 being slightly less than in 1999. This corresponds more closely with recent sales patterns of clay refractories. Major domestic markets for kaolin from Georgia, in decreasing order, were paper coating, paper filling, refractories, paint, and fiberglass (table 17).

The major domestic market for kaolin from South Carolina was rubber, accounting for about 41% of sales. Other major markets, in decreasing order, were catalysts, face and common brick, fiber glass, and roofing granules (table 19).

Absorbent Uses.—Sales for absorbent uses were about 3.07 Mt, an increase of 16% compared with that of 1999. Fuller's earth accounted for 71% of the clay used for absorbents, followed by bentonite. Pet waste absorbents accounted for approximately 90% of absorbent consumption, followed by oil and grease absorbents and miscellaneous absorbent applications.

Ceramics.—All varieties of clays were used in ceramics. Demand for clay in the manufacture of ceramics, ranging from china to sanitaryware to roofing granules, was approximately 2.00 Mt, a slight increase from that of 1999. The largest ceramics market was ceramic floor and wall tile (48%), followed by sanitaryware (18%), catalyst (12%), roofing granules (9%), fine china (3%), and pottery (3%). Ball clay accounted for 38% of the clay used in ceramics, followed by common clay and shale (36%) and kaolin (23%). Small amounts of bentonite, fire clay, and fuller's earth also were used in the manufacture of ceramics. Ball clay dominated the electrical porcelain, glazing, and sanitaryware markets. Common clay and shale was the predominant clay used in roofing granules. Kaolin dominated the catalyst market. Ball clay and common clay and shale were the predominant clays used in floor and wall tile manufacture, and ball clay and kaolin dominated the fine china markets.

Sales of clay tile increased slightly. Apparent consumption of clay floor and wall tile was 212 million square meters valued at $1.95 billion in 2000, an increase from 195 million square meters valued at $1.84 billion in 1999. Domestic manufacturers shipped 60.2 million square meters of clay floor and wall tile valued at $857 million in 2000 compared with 59.1 million square meters valued at $843 million in 1999. Imports were 155 million square meters valued at $1.12 billion in 2000 and 139 million square meters valued at $1.02 billion in 1999 (U.S. Census Bureau, 2001a).

Data on sales of vitreous sanitaryware used in the United States were not available for 2000. In 1999, apparent consumption was valued at $976 million compared with $886 million in 1998. Manufacturer shipments were $932 million in 1999 versus $883 million in 1998. Imports increased to $101

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million in 1999 from $68 million in 1998 (U.S. Census Bureau, 2000a).

Construction.—Common clay and shale were used to manufacture a wide variety of construction materials, including expanded aggregates, hydraulic cement, and structural clay products.

Expanded Clay and Shale.—Approximately 3.85 Mt of clay and shale was used in the production of lightweight aggregate (table 21). Nearly all the clay used to manufacture lightweight aggregate was common clay and shale. Lightweight aggregates were used in concrete block, structural concrete, and highway surfacing, in decreasing order of consumption.

Hydraulic Cement.—Clays provide the alumina and silica required to manufacture hydraulic cements. In 2000, approximately 4.19 Mt of clays was consumed, a decrease from 5.32 Mt in 1999. In decreasing order, common clay and shale, fire clay, fuller's earth, and kaolin were used in the manufacture of portland cement clinker. More than 92% of the clay consumed by the cement industry was common clay and shale.

Structural Clay Products.—Approximately 14.0 Mt of clays was used in the manufacture of structural clay products, such as building brick, roofing tile, and sewer pipe. Common and face brick accounted for 97% of this total. Other markets, in decreasing order by tonnage, were flue linings, sewer pipe, flower pots, structural tile, terra cotta, drain tile, and roofing. Small amounts of bentonite, fire clay, and kaolin also were used.

In 2000, 8.62 billion building and face bricks valued at $1.69 billion were shipped compared with 8.93 billion bricks valued at $1.63 billion in 1999. Structural facing tile and ceramic glazed brick shipments totaled 28,100 units valued at $13.2 million in 2000 compared with 26,70Q units valued at $14.6 million in 1999. Approximately 47,000 t of structural clay tile valued at $9.07 million was shipped in 2000 compared with 47,200 t valued at $8.49 million in 1999. Shipments of vitrified clay and sewer pipe fittings were 162,000 t valued at $61.7 million compared with 179,000 t valued at $56.6 million in 1999 (U.S. Census Bureau, 2001a).

Drilling Mud.—Sales (domestic and exports) for drilling mud applications were 764,000 t (676,000 t sold domestically and 88,100 t exported). Swelling-type bentonite accounted for approximately 93% of the clay used in drilling mud. Fuller's earth also was used in drilling mud applications.

Drilling activity increased in 2000 with the number of rotary rigs operating as of December 8, 2000, at 1,497 in Canada and the United States compared with 1,210 in 1999 (Oil & Gas Journal, 2000a). The number of exploratory wells drilled was predicted to increase to 2,550 in 2000 compared with 2,138 in 1999 (Oil & Gas Journal, 2000b).

Fillers, Extenders, and Binders.—Clays are used as fillers, extenders, and binders in a wide variety of products, such as adhesives, flooring products, paint, paper, and rubber. About 4.61 Mt of clays was sold for use as fillers, extenders, and binders in 2000 compared with 5.18 Mt in 1999. The bulk of the decline was in sales of kaolin to the paper industry. Paper coating and filling accounted for 72% of domestic sales, followed by paint, 8%; rubber, 5%; and animal feed, 3%. Adhesive; asphalt tile; fertilizer carrier; gypsum products; ink; medical, cosmetic, and pharmaceutical; pesticide carrier; plastic; textile; and wallboard applications each accounted for less than 1.5% of the fillers and extenders markets.

Kaolin accounted for approximately 89% of the clay used in filler and extender applications, followed by fuller's earth, 6%; common clay and shale, 2%; bentonite, 2%; ball clay, 1%; and trace amounts of fire clay. Bentonite was the predominant clay used for ink applications; common clay and shale, in wallboard production; fuller's earth, in fertilizer and pesticide applications; and kaolin, in adhesive, gypsum products, paint, paper, plastics, rubber, and textile markets. Bentonite, fuller's earth, and kaolin were the predominant clays used in asphalt tile, and bentonite and fuller's earth were the predominant clays used in animal feeds and pharmaceuticals.

The U.S. Census Bureau reported shipments of paints and coatings to be 1.48 billion gallons valued at $17.8 billion in 2000 compared with 1.47 billion gallons valued at $17.8 billion in 1999. Architectural paints accounted for 645 million gallons; product coatings, for 453 million gallons; and special purpose coatings, for 181 million gallons compared with 660 million gallons, 440 million gallons, and 174 million gallons, respectively, in 1999 (U.S. Census Bureau, 2001b). Architectural paints are the major market for industrial mineral fillers among the paint types.

Fiberglass.—Domestic sales to the fiberglass industry were 304,000 t in 2000 compared with 329,000 t in 1999. Kaolin was the only clay type used for this application.

Iron Ore Pelletizing.—Sales (domestic and exports) were 558,000 t in 2000 compared with 598,000 t in 1999. Swelling bentonite was the only type of clay used for this application.

Paper Products.—Kaolin accounted for all of the clay sales used for paper coating (2.82 Mt sold domestically and 1.93 Mt exported) and essentially all the clay used for paper filling (506,000 t sold domestically and 100,000 t exported).

Approximately 86.8 Mt of paper and paperboard was produced in 1999. Paperboard accounted for 46.2 Mt of this amount and paper accounted for 40.6 Mt. Paper accounted for 62% of the value of these shipments (McGraw-Hill Companies and International Trade Administration, 2000). In general, slow growth in the paper industry, pressure to reduce paper prices, and increased fuel costs have resulted in reduced returns for the kaolin industry.

Refractories.—Producers reported that 2.15 Mt of clays was used for the domestic manufacture of refractories. As mentioned earlier, it is believed that underreporting occurred in 2000. It is estimated that the reported tonnage should be increased by between 600,000 to 700,000 t, bringing sales for refractory usage to about 2.80 Mt compared with 3.06 Mt in 1999. The largest domestic markets, as reported by producers, were foundry sand (50%), refractory mortar and cement (16%), firebrick (12%), grogs and calcines (10%), alumina specialties (2%), and high alumina brick (1%). The market percentages for refractories must be used with caution for all but the foundry sand and the refractory mortar and cement categories because of the uncertainty in the data for specific market destinations.

Bentonite accounted for 39% of domestic refractory sales, followed by common clay and shale with 22%; kaolin, 20%; fire clay, 16%; ball clay, 3%; and fuller's earth, less than 1%. Fire clay and common clay were the predominate clays used in firebrick; bentonite, in foundry sand; common clay, in refractory mortar and cement; and kaolin, in calcine, grog, high alumina brick, and kiln furniture.

The U.S. Census Bureau reported that shipments of clay refractories were $911 million compared with $971 million in 1998. In 1999, 861,000 t (292 million bricks) valued at $518 million of clay refractory brick and shapes was shipped by

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manufacturers. This can be subdivided into fire clay brick and shapes, 384,000 t (118 million bricks) valued at $160 million; high alumina brick and shapes, 435,000 t (139 million bricks) valued at $301 million; and insulating brick and shapes, 41,800 t (36.0 million bricks) valued at $56.6 million. Shipments of unshaped clay refractories were 759,000 t valued at $393 million. This can be broken out into refractory mortars, 121,000 t valued at $60.6 million; plastic refractories, 144,000 t valued at $79.1 million; castable refractories, 325,000 t valued at $190 million; and fire clay gunning mixes, 169,000 t valued at $64.2 million. Approximately 150,000 t of miscellaneous refractories valued at $29.40 million and $24.9 million of other unknown types of clay refractories also was sold in 1999 (U.S. Census Bureau, 2000b).

Prices

Ball Clay.—The average value for ball clay reported by domestic producers was $42.46 per metric ton. The average values for imported and exported ball clay were $301.59 and $86.60 per ton, respectively.

Bentonite.—The average value reported by domestic producers for nonswelling bentonite was $35.00 per ton. The average value for swelling bentonite was $41.96 per ton. The average value for all bentonite was $41.22 per ton. The average value of imported bentonite was $345.93 per ton. The average value of exported bentonite was $105.52 per ton.

The price per ton, ex-works, Wyoming, crude, bulk, rail cars, was $23 to $54; foundry grade, bagged, rail cars, $42 to $65 per ton; API-grade, bagged, rail cars, $34 to $44 (Industrial Minerals, 2000f).

Southern Clay Products, Inc., announced average price increases of 6% for its wet-processed organoclay additives and 5% to 7% for its dry-processed organoclay additives (Southern Clay Products, 2000a, b).

Common Clay and Shale.—The average value for all common clay and shale produced in the United States and Puerto Rico was $5.70 per ton. The average value of clay and shale used in lightweight aggregate was $13.40 per ton. The value for lightweight aggregate is an estimate of the clay value. Average prices for lightweight aggregate produced from clay and shale range from $30 per ton to $50 per ton for most applications.

Fire Clay.—The average value for fire clay reported by domestic producers was $15.88 per ton. The average of imported fire clay was $383.56 per ton. The average value of exported fire clay was $86.11 per ton.

Fuller's Earth.—The average value of attapulgite-type fuller's earth was estimated to be $110 per ton. The value reported by producers on the USGS canvass and given in table 11 was believed to be greatly undervalued based on available pricing for attapulgite. The average value of montmorillonite-type fuller's earth was $90.00 per ton. The average value of all fuller's earth was estimated to be $91.83 per ton. The average value of imported fuller's earth was $171.43 per ton. The average value of exported fuller's earth was $183.82 per ton.

The price per ton, ex-plant, Georgia, 40% to 100% less than 325 mesh, truckload, was $181 to $454; granular processed, 40% to 100% less than 4/8 mesh, truckload, $159 to $454; granular, 6/30 mesh, truckload, $109 to $181; and granular, 6/30 mesh, gel grade, bagged, $295 to $635 (Industrial Minerals, 2000f).

Kaolin.—The average value of kaolin was $105.57 per ton for all kaolin grades. The average value for airfloat was $45.99 per ton; refractory grade (high-temperature calcined), $27.57; pigment grade (low-temperature calcined), $294.40; all types of calcined, $219.38 per ton; delaminated, $102.59 per ton; water washed, $100.00 per ton; and unprocessed, $12.57 per ton. The average value of the imported kaolin was $312.00 per ton. The average value of exported kaolin was $168.29 per ton.

The price per ton, ex-works, Georgia, filler, bulk, was $73 to $91; coating, bulk, $76 to $167; sanitaryware-grade, bagged, $53 to $62; tableware-grade, bagged, $114; and calcined, bulk, $305 to $357 (Industrial Minerals, 2000f).

IMERYS announced price increases of 8% for paper-grade kaolin prices. The company also will add energy surcharges of $3.30, $6.60, and $19.80 per ton for its hydrous slurry, hydrous dry, and calcined products, respectively (Chemical Market Reporter, 2000).

Foreign Trade

Ball Clay.—Ball clay exports decreased to 100,000 t valued at $8.66 million, according to the U.S. Census Bureau (table 23). Domestic ball clay producers reported that 164,000 t of ball clay was exported in 2000 (table 4). Some discrepancy may occur if water weight for slurry products is not taken into account. Sales through U.S. mineral brokers, where producers do not know if the ball clay is used domestically or exported, also could explain part of the discrepancy. Imports were 504 t of ball clay valued at $152,000 (table 24).

Bentonite.—Bentonite exports increased to 761,000 t valued at $80.3 million (table 23). Domestic bentonite producers reported exports of 404,000 t (table 6). The discrepancy between producers and the U.S. Census Bureau may result from producers including most of the exports destined for Canadian and Mexican markets (approximately 212,000 t) under domestic sales. Sales through U.S. mineral brokers, where producers do not know if the bentonite is used domestically or exported, also could explain part of the discrepancy.

Bentonite imports consisted mainly of untreated bentonite clay and chemically or artificially activated materials. Imports of untreated bentonite were 8,470 t valued at $2.93 million. Imports of chemically activated material were 17,600 t valued at $8.92 million (table 24).

Fire Clay.—Approximately 216,000 t of fire clay valued at $18.6 million was exported (table 23). In 2000, 73 t of fire clay valued at $28,000 was imported (table 24).

Fuller's Earth.—Approximately 136,000 t of fuller's earth valued at $25.0 million was exported (table 23). Approximately 70 t of decolorizing earth and fuller's earth valued at $12,000 was imported in 2000 (table 24).

Kaolin.—The U.S. Census Bureau reported that 3.69 Mt of kaolin valued at $621 million was exported in 2000 (table 23). Producers reported exports of 2.74 Mt (table 20). Much of the kaolin destined for Canadian paper markets (839,000 t) and some of the 219,000 t of kaolin exports for Mexican markets probably was reported under domestic consumption.

Kaolin imports increased to 62,500 t valued at $19.5 million (table 24). Approximately 75% of the imports was from Brazil, followed by the United Kingdom with 22%.

World Review

World production of bentonite was approximately 9.86 Mt (table 25), fuller's earth production was estimated to be 3.87 Mt

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(table 26), and kaolin production was 41.2 Mt (common clay and kaolin combined for Colombia, table 27). The United States continued to be the leading producer of all three varieties of clays, followed by Greece and countries of the former Soviet Union for bentonite, Germany for fuller's earth, and Uzbekistan, the United Kingdom, and the Republic of Korea for kaolin. Spain led all countries in the production of sepiolite.

The European Commission set a maximum dioxin concentration of 5 nanograms per kilogram in kaolinitic clay products used for binder, anticaking agents, and coagulants. This standard was established because of the high levels of dioxin in some of the kaolinitic clay from Germany (Industrial Minerals, 2000c).

Brazil.—Rio Capim Caulim SA, partially owned by IMERYS, plans to double its current production capacity of 400,000 t/yr and to introduce new calcined kaolin products for paint applications (Industrial Minerals, 2000a).

Czech Republic.—WBB purchased shares of Kaolin Hlubany, a.s., from Villeroy and Boch AG. Villeroy and Boch owned 94% of Kaolin Hlubany. The company sells about 80,000 t of clay for tableware, sanitaryware, refractory, and tile applications (Ceramic Industry, 2000).

Mexico.—KT Clay completed a $3.5 million expansion of its ball clay slurry plant at Monterrey. The plant, with the most recent expansion, has a capacity exceeding 100,000 t/yr (North American Minerals News, 2000c).

Namibia.—Afhold Ltd. obtained a 15-year license from the Namibian Government to mine sepiolite near Gobabis. The company plans to export the sepiolite to Europe for cat litter applications. The deposit contains 4 Mt of high-grade sepiolite and 5 Mt of lower quality sepiolite. The company will mine the lower quality material first (Mining Journal, 2000).

New Zealand.—IMERYS purchased all shares of New Zealand China Clays Ltd. from Ceramico Corp. Ltd. New Zealand China Clays produced about 15,000 t/yr of halloysite for the tableware market (CI Cybernews, 2000).

Portugal.—WBB created the management group WBB Portugal to handle its clay interests in that country. Portugal has become an important market for exports from the WBB Devon Clays Ltd. operation in the United Kingdom and its joint venture Donbas Clays JSC in Ukraine (Industrial Minerals, 2000i).

Turkmenistan.—Bentonite from the Oglanlinsky clay deposit will be processed at a new bentonite plant in Nebit-Dag, in the Balkansky District. The plant will have a capacity of 50,000 t/yr. The output will be used in ceramic, drilling-mud, and foundry applications (Industrial Minerals, 2000e).

Uzbekistan.—Kaolin, a joint venture between German and Uzbekistani interests, has commissioned a second kaolin processing plant at Angren. The new plant will increase capacity to 200,000 t/yr. The plant processes kaolin primarily for Uzbekistan's ceramic and paper industries, although its kaolin is suitable for pharmaceutical, pigment, and refractory applications (Industrial Minerals, 2000g).

Outlook

The outlook for the clay industry will be mixed for the next few years. Construction-oriented markets are likely to experience very little growth or even slight declines if the U.S. and world economies continue to slow. This will affect sales of clays for adhesives, brick, ceramics, fiber glass, lightweight aggregate, paint, and other construction-oriented markets. Similarly, a slowing economy will affect sales of clays for industrial manufacturing applications, such as foundry sand bond, iron ore pelletizing, and refractories. Interest in oil exploration and processing should provide a slight boost in sales for catalysts and drilling muds. Pet litter markets also should remain strong. Competition in the paper-filler and coating markets and increased fuel costs will continue to hamper the kaolin industry.

References Cited

American Ceramic Society Bulletin, 2000, Clay MACT update: American Ceramic Society Bulletin, v. 79, no. 1, January, p. 12.

Ceramic Industry, 2000, WBB makes acquisition: Ceramic Industry, v. 150, no. 2, February, p. 10.

Chemical Market Reporter, 2000, Market briefs: Chemical Market Reporter, v. 258, no. 21, November 20, p. 22.

CI Cybernews, 2000, IMERYS acquires New Zealand China Clays: CI Cybernews, v. 1, no. 1, May, 2 p.

Hecla Mining Co., 2001, Hecla signs agreement to sell industrial minerals subsidiaries to Imerys: Coeur d'Alene, ID, Hecla Mining Co. press release, February 27, 1 p.

Industrial Minerals, 2000, ...as Imerys acquires GCC units & shows a healthy H1 2000: Industrial Minerals, no. 397, October, p. 12.

———2000b, C-E Minerals buys NAPCO: Industrial Minerals, no. 388, January, p. 8.

———2000c, EC sets ceiling on dioxin in kaolinitic clay: Industrial Minerals, no. 388, January, p. 9.

———2000d, Kaoclay defines large Georgia kaolin resource: Industrial Minerals, no. 395, August, p. 13.

———2000e, New bentonite plant in Turkmenistan: Industrial Minerals, no. 393, June, p. 23.

———2000f, Prices: Industrial Minerals, no. 399, December, p. 74.

———2000g, Second kaolin plant for Angren: Industrial Minerals, no. 390, March, p. 33.

———2000h, Unimin to buy Albion Kaolin: Industrial Minerals, no. 392, May, p. 8.

———2000i, WBB Portugal division: Industrial Minerals, no. 390, March, p. 151.

McGraw-Hill Companies and International Trade Administration, 2000, Paper and allied products, chap. 10 *of* U.S. industry & trade outlook 2000: New York, McGraw-Hill, p. 10-1–10-12.

Mining Journal, 2000, Sepiolite plan approved: Mining Journal, v. 335, no. 8606, October 27, p. 338.

North American Minerals News, 2000a, Amcol breaks ground for Georgia blending facility: North American Minerals News, no. 59, April, p. 6.

———2000b, Hecla puts KT Clay up for sale or auction: North American Minerals News, no. 64, September, p. 16.

———2000c, KT Clay completes slurry plant expansion: North American Minerals News, no. 63, August, p. 3.

———2000d, Southern Clay gets new owner as Laporte sells to KKR: North American Minerals News, no. 67, December, p. 6.

———2000e, Thiele Kaolin enters marketing relationship with CVRD: North American Minerals News, no. 63, August, p. 7.

———2000f, Unimin acquires United Clays: North American Minerals News, no. 56, January, p. 4.

Oil & Gas Journal, 2000a, Statistics: Oil & Gas Journal, v. 98, no. 51, December 18, p. 161-162.

———2000b, US, Canada should see robust drilling this year: Oil & Gas Journal, v. 98, no. 5, January 31, p. 64-65.

Southern Clay Products, Inc., 2000a, Southern Clay Products announces price increase effective December 1: Gonzales, TX, Southern Clay Products, Inc., press release, November 13, 1 p.

———2000b, Southern Clay Products announces price increase effective December 15: Gonzales, TX, Southern Clay Products, Inc., press release, December 6, 1 p.

———2000c, Southern Clay smectite plant: Gonzales, TX, Southern Clay Products, Inc., press release, July 25, 1 p.

———2000d, U.S. Distric Court in Houston, Texas finds in favor of Southern Clay Products, Inc. patent infringement case: Gonzales, TX, Southern Clay Products, Inc., press release, June 9, 1 p.

U.S. Census Bureau, 2000a, Plumbing fixtures—Fourth quarter 1999: U.S. Census Bureau, MQ332E(99)-5, October, 24 p.

———2000b, Refractories—1999: U.S. Census Bureau, MA327C(99)-1, September, 10 p.

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———2001a, Clay construction products—Summary 2000: U.S. Census Bureau, MQ327D(00)-5, August, 13 p.
———2001b, Paint, varnish, and lacquer—2000: U.S. Census Bureau, MQ325F(00)-4, March, 3 p.
U.S. Food and Drug Administration, 2000, Guidance for industry—Dioxin in anti-caking agents used in animal feed and feed ingredients—Availability: Federal Register, v. 65, no. 76, April 19, p. 20996-20997.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Clays. Ch. in Mineral Commodity Summaries, annual.
Clays. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

American Forest and Paper Association.
China Clay Producers Association.
Clays. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Cosmetic, Toiletry, and Fragrance Association.
Engineering and Mining Journal.
Mining Engineering.
Mining Magazine.
National Paint and Coatings Association.
Society of the Plastics Industry.
World Mining.

TABLE 1
SALIENT U.S. CLAY STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
Domestic clays sold or used by producers:					
Quantity	43,100	42,000	41,900	42,200	40,800
Value	1,710,000	1,670,000	1,670,000	1,570,000	1,520,000
Exports:					
Quantity	4,830	5,080	5,230	4,800	5,260
Value	825,000	860,000	843,000	823,000	896,000
Imports for consumption:					
Quantity	45	64	86	90	96
Value	21,000	23,200	27,700	23,000	34,900

1/ Excludes Puerto Rico.
2/ Data are rounded to no more than three significant digits.

TABLE 2
CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	2,090	--	--	W	2,090	23,200
Arizona	--	W	W	--	--	--	W	W
Arkansas	--	--	958	--	--	W	958	1,170
California	--	21	969	W	W	W	990	19,000
Colorado	--	W	296	W	--	--	296	2,000
Connecticut	--	--	55	--	--	--	55	183
Florida	--	--	W	--	W	33	33	3,420
Georgia	--	--	1,500	--	919	7,660	10,100	964,000
Illinois	--	--	200	--	W	--	200	905
Indiana	--	--	639	--	--	--	639	1,560
Iowa	--	--	306	--	--	--	306	1,060
Kansas	--	--	594	--	W	--	594	3,970
Kentucky	W	--	1,000	10	--	--	1,010	4,220
Louisiana	--	--	636	--	--	--	636	1,530
Maine	--	--	49	--	--	--	49	125
Maryland	--	--	271	--	--	--	271	982
Massachusetts	--	--	36	--	--	--	36	321
Michigan	--	--	594	--	--	--	594	3,210
Minnesota	--	--	14	--	--	--	14	15
Mississippi	W	W	484	--	371	--	856	32,300
Missouri	--	--	1,050	351	W	--	1,400	7,860
Montana	--	W	W	--	--	--	W	W
Nebraska	--	--	133	--	--	--	133	338
Nevada	--	6	--	--	28	W	35	4,670

See footnotes at end of table.

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TABLE 2--Continued
CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
New Jersey	--	--	W	--	--	--	W	130
New Mexico	--	--	34		--	--	34	256
New York	--	--	630	--	--	--	630	7,820
North Carolina	--	--	2,430	--	--	W	2,430	18,600
North Dakota	--	--	79	--	--	--	79	W
Ohio	--	--	1,370	W	--	--	1,370	7,380
Oklahoma	--	--	757	--	--	--	757	2,060
Oregon	--	W	227	--	--	--	227	632
Pennsylvania	--	--	840	--	--	--	840	1,870
South Carolina	--	--	890	40	--	397	1,330	24,700
South Dakota	--	--	171	--	--	--	191	W
Tennessee	685	--	W	--	W	W	685	29,300
Texas	W	W	2,210	--	W	W	2,210	9,460
Utah	--	W	335	--	--	--	335	5,380
Virginia	--	--	1,010	--	W	--	1,010	2,380
Washington	--	--	116	--	--	--	116	425
West Virginia	--	--	199	--	--	--	199	560
Wyoming	--	3,080	W	--	--	--	3,080	126,000
Total	1,140	3,760	23,700	476	2,910	8,800	40,800	1,520,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Excludes Puerto Rico.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3
BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	Airfloat		Water-slurried		Unprocessed		Total	
State	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1999:								
Tennessee	323	15,700	184	7,410	218	7,000	725	30,100
Other 2/	194	9,230	9	400	270	8,330	472	18,000
Total	517	24,900	193	7,810	488	15,300	1,200	48,000
2000:								
Tennessee	287	14,400	180	7,660	218	7,160	685	29,300
Other 2/	212	11,500	W	W	W	W	456	19,100
Total	499	26,000	180	7,660	218	7,160	1,140	48,400

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Kentucky, Mississippi, and Texas.

TABLE 4
BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Fillers, extenders, binders 2/	W	W
Floor and wall tile	353,000	400,000
Miscellaneous ceramics 3/	72,900	151,000
Pottery	121,000	22,700
Refractories 4/	42,200	68,500
Sanitaryware	292,000	256,000
Miscellaneous 5/	155,000	78,600
Exports 6/	161,000	164,000
Total	1,200,000	1,140,000

See footnotes at end of table.

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TABLE 4--Continued
BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes animal feed (1999), asphalt emulsions (1999), rubber (2000), and other fillers, extenders, and binders.
3/ Includes catalysts, electrical porcelain, fiber glass (2000), fin china/dinnerware, glazes, mineral wool, and miscellaneous ceramics.
4/ Includes firebrick, blocks, shapes, high-alumina brick and specialties (1999), and kiln furniture (2000).
5/ Includes brick (common), waterproofing seals, drilling mud (1999), and other unknown uses (1999).
6/ Includes ceramics and glass, fillers, extenders and binders, and floor and wall tile.

TABLE 5
BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Nonswelling		Swelling		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1999:						
California	W	W	W	W	23	2,110
Mississippi	W	W	--	--	W	W
Nevada	W	W	W	W	6	W
Oregon	--	--	W	W	W	W
Wyoming	--	--	3,370	146,000	3,370	146,000
Other 2/	392	13,200	305	16,400	668	27,500
Total	392	13,200	3,680	163,000	4,070	176,000
2000:						
California	W	W	W	W	21	2,160
Mississippi	W	W	--	--	W	W
Nevada	W	W	W	W	6	W
Oregon	--	--	W	W	W	W
Wyoming	--	--	3,080	126,000	3,080	126,000
Other 2/	400	14,000	285	14,400	658	26,200
Total	400	14,000	3,360	141,000	3,760	155,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Alabama, Arizona, Colorado, Montana, Texas, and Utah.

TABLE 6
BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Metric tons)

Use	1999	2000
Domestic:		
Absorbents:		
Pet waste absorbents	788,000	862,000
Other absorbents	W	W
Adhesives	14,200	5,680
Animal feed	74,200	46,800
Ceramics (except refractories) 2/	W	W
Drilling mud	667,000	654,000
Filler and extender applications 3/	24,700	35,400
Filtering, clarifying, decolorizing mineral oils and greases, vegetable oils, dessicants	81,400	93,800
Foundry sand	888,000	835,000
Pelletizing (iron ore) 4/	540,000	500,000
Miscellaneous refractories 5/	201,000	4,050
Miscellaneous 6/	83,300	66,800
Waterproofing and sealing	268,000	254,000
Total	3,630,000	3,360,000

See footnotes at end of table.

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TABLE 6--Continued
BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Metric tons)

Use	1999	2000
Exports:		
Drilling mud	68,800	56,400
Foundry sand	251,000	233,000
Other 7/	121,000	115,000
Total	440,000	404,000
Grand total	4,070,000	3,760,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes catalysts and pottery.
3/ Includes medical, pharmaceutical, cosmetics, paint, paper filling (2000), pesticides and related products (1999), plastics, asphalt tiles, ink, and miscellaneous fillers and extenders applications.
4/ Excludes shipments to Canada. Total sales in North America were 598,000 metric tons in 1999 and 558,000 metric tons in 2000.
5/ Includes kiln furniture and miscellaneous refractories.
6/ Includes chemical manufacturing, heavy clay products, and other unknown uses.
7/ Includes absorbents, waterproofing and sealing, fillers and extenders, pelletizing, miscellaneous refractories, and other unknown uses.

TABLE 7
COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1999		2000	
	Quantity	Value	Quantity	Value
Alabama	2,320	23,700	2,090	23,200
Arkansas	1,010	1,510	958	1,170
California	829	13,100	969	16,800
Georgia	1,600	5,130	1,500	5,200
Indiana	752	1,480	639	1,560
Kansas	592	2,770	594	3,970
Kentucky	892	3,790	1,000	4,190
Michigan	615	3,550	594	3,210
Mississippi	497	3,390	484	2,200
Missouri	1,080	4,180	1,050	3,240
New York	W	W	630	7,820
North Carolina	2,430	18,700	2,430	18,600
Ohio	1,710	8,170	1,370	7,380
Oklahoma	757	2,050	757	2,060
Pennsylvania	816	1,760	840	1,870
South Carolina	1,130	4,930	890	2,790
Texas	2,100	9,890	2,210	9,460
Virginia	881	3,240	1,010	2,380
Other 3/	4,820	44,100	3,730	17,400
Total	24,800	155,000	23,700	135,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes Puerto Rico.
3/ Includes all other States except Alaska, Delaware, Hawaii, Idaho, Nevada, New Hampshire, Rhode Island, Vermont, and Wisconsin.

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TABLE 8
COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Metric tons)

Use	1999	2000
Ceramics and glass 3/	181,000	W
Civil engineering and sealing	34,800	28,000
Floor and wall tile:		
Ceramic	400,000	517,000
Other 4/	W	W
Heavy clay products:		
Brick, extruded	12,000,000	11,600,000
Brick, other	1,800,000	1,730,000
Drain tile and sewer pipe	27,000	71,900
Flowerpots	W	W
Flue linings	58,900	259,000
Structural tile	22,700	W
Other 5/	160,000	108,000
Lightweight aggregate:		
Concrete block	2,430,000	2,330,000
Highway surfacing	317,000	239,000
Structural concrete	929,000	941,000
Miscellaneous 6/	259,000	344,000
Portland and other cements	5,010,000	4,030,000
Refractories 7/	785,000	472,000
Miscellaneous 8/	429,000	1,060,000
Total	24,800,000	23,700,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Miscellaneous."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes Puerto Rico.
3/ Includes pottery and roofing granules.
4/ Includes quarry tile and miscellaneous floor and wall tiles.
5/ Includes flower pots, roofing tile, terra cotta (2000), and miscellaneous clay products.
6/ Includes miscellaneous lightweight aggregates.
7/ Includes firebrick, block and shapes, mortar and cement, and miscellaneous refractories.
8/ Includes exports, miscellaneous fillers and extenders, asphalt emulsion, asphalt tile (2000), wall board, and other unknown uses.

TABLE 9
FIRE CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
State	Quantity	Value	Quantity	Value
Missouri	293	3,980	351	4,630
Other 3/	109	2,790	125	2,940
Total	402	6,770	476	7,560

1/ Refractory uses only.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes California, Colorado (2000), Kentucky, New Mexico (1999), Ohio, and South Carolina.

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TABLE 10
FIRE CLAY SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Ceramics and glass 2/	W	W
Heavy clay products and lightweight aggregates 3/	47,400 r/	101,000
Refractories:		
Firebrick, block, shapes	154,000	140,000
Other refractories 4/	172,000	208,000
Miscellaneous 5/	28,800 r/	26,900
Total	402,000	476,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes pottery.
3/ Includes common brick, portland cement, terra cotta.
4/ Includes foundry sand, grogs and calcines, high alumina brick and specialties (1999), mortar and cements, and miscellaneous refractories.
5/ Includes animal feed, quarry tile, and other unknown uses.

TABLE 11
FULLER'S EARTH SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	Attapulgite 2/		Montmorillonite		Total	
State	Quantity	Value	Quantity	Value	Quantity	Value
1999:						
Georgia	W	W	W	W	725	73,800
Southern States 3/	--	--	1,030	79,000	1,030	79,000
Western States 4/	W	W	W	W	808	78,600
Total	289 r/	13,200 r/	2,280 r/	218,000 r/	2,560	231,000
2000:						
Georgia	W	W	W	W	919	81,400
Southern States 3/	--	--	996	79,400	996	79,400
Western States 4/	W	W	W	W	995	93,100
Total	292	13,500 5/	2,620	240,000	2,910	254,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Southern States."
-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Primaily gellent-grade fuller's earth. See discussion under "Production: Fuller's earth."
3/ Includes Florida, Mississippi, Tennessee, and Virginia.
4/ Includes California, Illinois, Kansas, Missouri, Nevada, and Texas.
5/ See discussion of fuller's earth under "Prices."

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TABLE 12
FULLER'S EARTH SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Absorbents:		
Oil and grease absorbent	275,000	276,000
Pet waste absorbent	1,580,000	1,920,000
Miscellaneous absorbent	W	--
Animal feed	82,900	83,100
Drilling mud	W	W
Fertilizers	137,000	62,500
Fillers, extenders, binders 2/	63,900	70,200
Filtering, clarifying, decolorizing animal, mineral, vegetable oils and greases	W	72,300
Pesticides and related products	67,800	79,500
Miscellaneous 3/	245,000	347,000
Exports 4/	114,000	W
Total	2,560,000	2,910,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes adhesives; asphalt emulsions and tiles; gypsum products; medical, pharmaceutical, and cosmetics; paint; textiles; and other unknown uses.
3/ Includes portland cement, refractories, roofing granules, and other unknown uses.
4/ Includes absorbents; drilling mud; fillers, extenders, and binders; floor and wall tiles; and other unknown uses.

TABLE 13
KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
State	Quantity	Value	Quantity	Value
Georgia	8,160	907,000	7,660	877,000
South Carolina	408	15,700	397	21,900
Other 2/	588	25,800	742	30,400
Total	9,160	948,000	8,800	929,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Alabama, Arkansas, California, Florida, Nevada, North Carolina, Tennessee, and Texas.

TABLE 14
KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY KIND 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
Kind	Quantity	Value	Quantity	Value
Airfloat	1,030	46,100	1,420	65,300
Calcined 2/	1,830	272,000	1,190	261,000
Delaminated	1,350	132,000	1,160	119,000
Unprocessed	363	3,250	210	2,640
Water washed	4,590	495,000	4,820	482,000
Total	9,160	948,000	8,800	929,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes pigment- and refractory-grade calcined kaolin; see discussion under "Production: Kaolin."

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TABLE 15
CALCINED KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Refractory-grade		Pigment-grade	
	Quantity	Value	Quantity	Value
1999:				
Alabama and Georgia	W	W	799	250,000
Other 2/	W	W	(3/)	(3/)
Total	1,030	22,400	799	250,000
2000:				
Alabama and Georgia	W	W	839	247,000
Other 2/	W	W	(3/)	(3/)
Total	354 4/	9,760	839	247,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Arkansas, California, and Texas.
3/ Included with refractory-grade kaolin to avoid disclosing company proprietary data.
4/ See discussion under "Production: Kaolin."

TABLE 16
GEORGIA KAOLIN SOLD OR USED BY PRODUCERS,
BY KIND 1/

(Thousand metric tons and thousand dollars)

Kind	1999		2000	
	Quantity	Value	Quantity	Value
Airfloat	654	26,800	616	29,200
Calcined 2/	799	250,000 3/	1,070	248,000
Delaminated	1,350	132,000	1,160	119,000
Unprocessed	W	W	61	655
Water washed	4,540	494,000	4,760	480,000
Total	8,160	907,000	7,660	877,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes pigment- and refractory-grade calcined kaolin; also see discussion under "Production: Kaolin."
3/ Excludes value for refractory-grade kaolin; included in "Total."

TABLE 17
GEORGIA KAOLIN SOLD OR USED BY PRODUCERS,
BY USE 1/ 2/

(Metric tons)

Use	1999	2000
Domestic:		
Ceramics and glass:		
Catalysts (oil-refining)	W	W
Electrical porcelain	8,550	W
Fiber glass	301,000	277,000
Roofing granules	25,000	22,200
Sanitaryware	67,000	82,900
Other 3/	212,000	218,000

See footnotes at end of table.

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TABLE 17–Continued
GEORGIA KAOLIN SOLD OR USED BY PRODUCERS, BY USE 1/ 2/

(Metric tons)

Use	1999	2000
Fillers, extenders, binders:		
Adhesives	66,500	55,600
Paint	263,000	290,000
Paper coating	2,990,000	2,810,000
Paper filling	784,000	505,000
Plastic	34,600	49,600
Rubber	85,200	64,400
Other 4/	104,000	100,000
Heavy clay products 5/	W	17,400
Refractories 6/	650,000	278,000
Undistributed 7/	179,000	182,000
Total	5,770,000	4,960,000
Exports:		
Paint	81,500	400,000
Paper coating 8/	1,970,000	1,930,000
Paper filling 8/	110,000	100,000
Rubber	4,670	7,670
Undistributed 9/	234,000	263,000
Total	2,400,000	2,700,000
Grand total	8,160,000	7,660,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."
1/ Includes airfloat, high- and low-temperature calcined and delaminated, water-washed, and unprocessed kaolin.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes crockery/earthenware, fine china/dinnerware, pottery, and miscellaneous ceramics.
4/ Includes animal feed; asphalt tile; fertilizers; gypsum products; medical, pharmaceutical, and cosmetics applications; pesticides and related products; textiles; and miscellaneous fillers, extenders, and binders.
5/ Includes brick (common and face), portland cement (1999), and miscellaneous clay products.
6/ Includes firebricks, blocks and shapes, grogs and calcines, high-alumina specialties, kiln furniture (2000), and miscellaneous refractories; also see discussion under "Production: Kaolin."
7/ Includes chemical manufacturing, floor and wall tiles, and other unknown uses.
8/ Some export sales may be included under domestic sales.
9/ Includes adhesives; catalyst (oil-refining); fiberglass; sanitaryware; miscellaneous fillers, extenders, and binders; portland cement; miscellaneous refractories (1999); and other unknown uses (1999).

TABLE 18
SOUTH CAROLINA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
Kind	Quantity	Value	Quantity	Value
Airfloat	338	15,100	337	21,400
Unprocessed	70	554	61	485
Total	408	15,700	397	21,900

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 19
SOUTH CAROLINA KAOLIN SOLD OR USED
BY PRODUCERS, BY KIND AND USE 1/

(Metric tons)

Kind and use	1999	2000
Adhesives	15,000	12,700
Ceramics 2/	W	W
Fertilizers, pesticides, related products	W	W
Fiberglass	W	W
Paper coating and filling	W	W
Plastics	W	W
Rubber	137,000	161,000
Refractories 3/	W	W
Other 4/	215,000	224,000
Exports 5/	41,100	W
Total	408,000	397,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes fine china/dinnerware; glazes, glass, and enamels; pottery; roofing granules; sanitaryware; and miscellaneous ceramics.
3/ Includes firebrick, blocks and shapes, and miscellaneous refractories.
4/ Includes asphalt tile; brick (common and face); catalysts (oil-refining); civil engineering and sealings; gypsum products; paint; miscellaneous fillers, extenders, and binders; and other unknown uses.
5/ Includes fillers, extenders, and binders.

TABLE 20
KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Domestic:		
Ceramics:		
Catalyst (oil and gas refining)	208,000	219,000
Electrical porcelain	12,700	7,890
Fine china and dinnerware	23,500	28,700
Floor and wall tile	39,800	49,400
Pottery	11,200	13,500
Roofing granules	43,200	38,700
Sanitaryware	75,600	90,600
Miscellaneous	26,300	8,420
Chemical manufacture	23,200	31,200
Civil engineering	W	W
Fiberglass, mineral wool	329,000	304,000
Fillers, extenders, binders:		
Adhesive	81,500	68,300
Fertilizer	W	4,050
Medical, pharmaceutical, cosmetic	W	W
Paint	288,000	326,000
Paper coating	3,000,000	2,820,000
Paper filling	791,000	506,000
Pesticides	13,100	W
Plastic	39,700	53,100
Rubber	222,000	226,000
Miscellaneous	115,000	115,000
Heavy clay products:		
Brick, common and face	126,000	126,000
Portland cement	54,200	81,100

See footnotes at end of table.

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TABLE 20--Continued
KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1999	2000
Domestic--Continued:		
Refractories: 2/		
Firebrick, block and shapes	13,800	13,600
Grogs and calcines	135,000	153,000
High-alumina brick, specialties, kiln furniture	W	W
Foundry sand, mortar, cement, miscellaneous refractories	621,000	257,000
Miscellaneous applications	430,000	514,000
Total	6,720,000	6,050,000
Exports:		
Ceramics	210,000	228,000
Foundry sand, grogs and calcines, other refractories	W	--
Paint	88,100	412,000
Paper coating	1,970,000	1,930,000
Paper filling	110,000	100,000
Rubber	45,700	33,700
Miscellaneous	23,800	38,100
Total	2,440,000	2,740,000
Grand total	9,160,000	8,800,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous" or "Miscellaneous applications." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Also see discussion under "Consumption: Kaolin" and "Consumption: Refractories."

TABLE 21
COMMON CLAY AND SHALE USED IN LIGHTWEIGHT AGGREGATE PRODUCTION IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Concrete block	Structural concrete	Highway surfacing	Other	Total	Total value e/
1999:						
Alabama and Arkansas	713	8	8	--	729	15,000
California e/	41	160	--	--	201	7,990
Florida and Indiana	229	48	--	--	277	1,520
Kansas, Kentucky, Louisiana	358	219	86	76	740	12,000
Missouri	--	--	--	135	135	1,780
New York	284	220	--	--	503	15,300
North Carolina e/	300	52	--	--	352	4,050
Ohio and Oklahoma	258	16	--	--	274	1,620
Texas e/	49	157	222	31	459	2,520
Utah and Virginia	193	48	--	16	259	3,520
Total	2,430	929	317	259	3,930	65,200
2000:						
Alabama and Arkansas	848	131	8	--	987	15,300
California	53	220	--	--	272	10,600
Florida and Indiana	205	34	--	--	236	1,570
Kansas, Kentucky, Louisiana	409	227	9	91	735	2,830
Missouri	--	--	--	122	122	1,820
New York	82	54	--	--	136	5,600
North Carolina e/	301	52	--	--	353	4,050
Ohio and Oklahoma	170	11	--	--	182	1,420
Texas e/	49	157	222	31	459	2,520
Utah and Virginia	209	59	--	100	367	5,860
Total	2,330	941	239	344	3,850	51,600

e/ Estimated. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 22
COMMON CLAY AND SHALE USED IN BUILDING BRICK PRODUCTION
IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1999		2000	
	Quantity	Value	Quantity	Value
Alabama	877	2,120 r/	910	2,200
Arkansas	739	704 r/	479	366
California	249	1,030	251	734
Colorado	286	2,240	224	1,790
Connecticut, New Jersey, 3/ New York 3/	247	1,070	358	1,640
Georgia	1,300	3,540	1,150	3,140
Illinois	133 r/	609 r/	188	804
Indiana and Iowa	389	1,250 r/	395	1,250
Kentucky 3/ and Tennessee 3/	906 r/	2,300	789	2,100
Maryland and West Virginia 4/	385	1,480	317	1,060
Mississippi and Missouri	508	2,190	531	2,240
North Carolina	1,980	13,300	1,990	13,300
Ohio	929	4,500	845	4,370
Oklahoma	476	1,110	455	975
Pennsylvania	718	1,360	743	1,470
South Carolina	919	3,780 r/	876	2,720
Texas	1,000	5,890 r/	1,110	4,960
Virginia	740	2,580 r/	687	1,200
Other 5/	1,000 r/	3,350 r/	1,050	3,480
Total	13,800	54,400 r/	13,300	49,800

r/ Revised.
1/ Includes extruded and other brick.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Extruded brick only.
4/ Includes other brick only.
5/ Includes Arizona, Kansas, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Nebraska, New Mexico, North Dakota, Utah, Washington, and Wyoming (1999).

TABLE 23
U.S. EXPORTS OF CLAYS IN 2000, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	1	194	(2/)	33	(2/)	122
Australia	4	86	11	855	10	843	--	--
Belgium	(2/)	4	1	401	--	--	2	222
Brazil	(2/)	72	14	5,140	(2/)	92	1	882
Canada	38	3,850	188	14,600	5	984	76	13,000
Finland	--	--	--	--	--	--	(2/)	11
France	--	--	66	3,040	(2/)	6	(2/)	6
Germany	8	225	10	1,060	(2/)	32	1	128
Indonesia	--	--	5	1,170	(2/)	39	5	733
Italy	2	1,000	9	606	--	--	3	857
Japan	5	153	157	16,500	66	3,960	1	245
Korea, Republic of	(2/)	30	27	3,340	5	2,000	--	--
Malaysia	(2/)	41	23	1,780	--	--	2	195
Mexico	11	385	24	1,690	66	4,750	1	145
Netherlands	(2/)	60	41	3,860	23	1,260	24	3,450
Singapore	(2/)	53	10	1,480	--	--	1	268
South Africa	(2/)	10	1	311	--	--	(2/)	13
Taiwan	(2/)	68	25	3,860	7	399	(2/)	21
Thailand	(2/)	107	20	2,030	--	--	(2/)	33
United Kingdom	1	34	79	5,680	(2/)	87	5	813
Venezuela	16	1,350	12	2,020	1	238	1	144
Other	15	1,140	37	10,700	33	3,930	13	3,720
Total	100	8,660	761	80,300	216	18,600	136	25,000

See footnotes at end of table.

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TABLE 23--Continued
U.S. EXPORTS OF CLAYS IN 2000, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	Kaolin		Clays, n.e.c. 3/		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	4	1,040	2	2,070	7	3,460
Australia	28	12,900	4	2,870	57	17,600
Belgium	21	6,220	1	1,850	25	8,690
Brazil	4	1,260	6	3,470	25	10,900
Canada	839	89,900	144	32,700	1,290	155,000
Finland	374	66,000	1	2,170	375	68,200
France	7	2,060	1	1,070	75	6,190
Germany	22	8,640	5	4,600	46	14,700
Indonesia	86	18,900	3	1,600	100	22,400
Italy	156	32,200	2	787	171	35,500
Japan	947	165,000	13	7,760	1,190	194,000
Korea, Republic of	161	38,300	9	5,720	203	49,400
Malaysia	2	663	1	1,050	28	3,730
Mexico	219	20,800	34	6,560	356	34,300
Netherlands	282	46,100	17	12,900	387	67,700
Singapore	2	686	3	3,580	16	6,060
South Africa	7	2,280	4	1,840	13	4,450
Taiwan	158	19,800	7	2,930	198	27,000
Thailand	21	5,680	3	1,800	44	9,650
United Kingdom	37	9,990	19	13,100	142	29,700
Venezuela	14	1,440	9	3,920	52	9,110
Other	300	70,400	69	27,900	463	118,000
Total	3,690	621,000	357	142,000	5,260	896,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Also includes chamotte or dina's earth, activated clays and earths, and artificially activated clays.

Source: U.S. Census Bureau.

TABLE 24
U.S. IMPORTS FOR CONSUMPTION OF CLAY IN 2000, BY KIND 1/

Kind	Quantity (metric tons)	Value 2/ (thousands)
China clay or kaolin:		
Brazil	47,000	14,300
Canada	641	220
France	296	92
Germany	459	151
Japan	119	169
Mexico	138	115
United Kingdom	13,700	4,370
Other	187	159
Total	62,500	19,500
Fire clay:		
Burkina	70	18
Italy	2	5
Korea, Republic of	1	5
Total	73	28
Decolorizing earths and fuller's earth, China	70	12
Bentonite:		
Canada	225	127
Germany	183	107
Japan	28	118

See footnotes at end of table.

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TABLE 24--Continued
U.S. IMPORTS FOR CONSUMPTION OF CLAY IN 2000, BY KIND 1/

Kind	Quantity (metric tons)	Value 2/ (thousands)
Bentonite--Continued:		
Mexico	110	115
Netherlands	569	95
Turkey	4,830	1,350
United Kingdom	2,420	966
Other	99	58
Total	8,470	2,930
Common blue clay and other ball clay:		
China	1	3
United Kingdom	503	149
Total	504	152
Other clay:		
Canada	2,460	789
China	586	554
Germany	448	320
Spain	1,030	532
United Kingdom	837	490
Other	867	628
Total	6,220	3,310
Chamotte or dina's earth, Germany	2	11
Artificially activated clay and activated earth:		
Austria	302	436
Canada	2,320	1,090
Germany	2,280	2,370
Mexico	11,900	4,070
Netherlands	130	61
Norway	72	23
Slovenia	177	232
Venezuela	155	60
Other	315	570
Total	17,600	8,920
Grand total	95,500	34,900

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ U.S. Customs declared value.

Source: U.S. Census Bureau.

TABLE 25
BENTONITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Algeria 4/	17,200	17,657	15,655	15,491 r/	22,708 5/
Argentina	134,588	113,572	131,320	152,300 r/	150,000
Armenia	2,750	2,750 e/	3,000 e/	3,993 r/	2,807 5/
Australia e/ 4/	79,200 r/	73,100 r/	104,000 r/	180,000 r/	180,000
Bosnia and Herzegovina e/	800	800	800	800	800
Brazil (beneficiated)	186,000	230,000 r/	220,000 r/	274,623 r/	275,000
Bulgaria	202,000	171,000 e/	175,000 e/	175,000	150,000
Burma	4,769	4,908	3,871	728 r/	600
Chile	1,191	717	721	1,104 r/	1,314 5/
Croatia	9,728	7,331	7,581	8,441	10,013 5/
Cyprus	70,927	98,700 r/	121,850 r/	138,853 r/	126,313 5/
Czech Republic	59,000	110,000	125,000	160,000	150,000
Egypt e/	50,000 r/	50,000 r/	50,000 r/	50,000 r/	50,000
Georgia	13,000	12,000	11,000 e/	12,000	12,000
Germany	491,000	510,000 e/	500,000 e/	500,000	500,000
Greece	973,517	950,000 e/	950,000 e/	950,000	950,000

See footnotes at end of table.

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TABLE 25--Continued
BENTONITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Guatemala	3,755	3,750	3,800 e/	3,800	3,800
Hungary	15,376	14,848	17,000	16,000	15,000
Indonesia	26,000 e/	653,623	840	5,213	6,000
Iran 6/	85,000 e/	105,300	83,279 r/	64,957 r/	70,000
Italy	475,000	513,000	592,000	500,000	500,000
Japan	468,728	495,646	443,566	428,247 r/	445,115 5/
Macedonia e/	30,000	30,000	30,000	30,000	30,000
Mexico	69,810	111,503	185,729	208,611	269,730 5/
Morocco	39,680	49,633	47,881	36,528 r/	21,352 5/
Mozambique	11,051	13,799	14,000 e/	10,828 r/	16,144 5/
New Zealand (processed)	13,734	12,802	14,000 e/	15,000	10,000
Pakistan	15,290	16,450	14,196	15,349	27,700 5/
Peru	18,592	20,171 r/	19,659 r/	19,659 r/	21,059 5/
Philippines	8,000 e/	8,000 e/	3,900 r/	1,844	2,000
Poland 7/	6,200 r/	6,100 r/	5,400 r/	6,000 r/	6,000
Romania	43,543	27,133	25,434	19,577 r/	35,789 5/
Serbia and Montenegro	95	100 e/	68	77	75
South Africa 8/	48,076	33,326	48,382	50,363 r/	85,187 5/
Spain	151,155	150,000 e/	150,000 e/	150,000	150,000
Tanzania e/	75	75	75	75	75
Turkey	515,452	521,158	565,708	560,000	560,000
Turkmenistan e/	50,000	50,000	50,000	50,000	50,000
Ukraine e/	300,000	300,000	300,000	300,000	300,000
U.S.S.R., former e/ 9/	900,000	800,000	600,000	700,000	750,000
United States	3,740,000	4,020,000	3,820,000	4,070,000	3,760,000 5/
Zimbabwe 8/	185,953	186,000 e/	135,785	140,000	140,000
Total	9,510,000 r/	10,500,000 r/	9,590,000 r/	10,000,000 r/	9,860,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through August 21, 2001.
3/ In addition to the countries listed, Canada and China are believed to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of output levels.
4/ Includes bentonitic clays.
5/ Reported figure.
6/ Year beginning March 21 of that stated.
7/ Montmorillite type bleaching clay.
8/ May include other clays.
9/ Dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual countries, except Armenia, Georgia, Turkmenistan, and Ukraine.

TABLE 26
FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Algeria e/	4,500	4,500	4,500	2,489 r/ 4/	3,431 4/
Argentina e/	1,500	1,500	1,500	1,500	1,500
Australia (attapulgite)	17,173 r/	28,262 r/	15,670 r/	5,639 r/	5,000
Germany (unprocessed)	491,000	511,000	500,000 e/	500,000 e/	500,000
Italy	26,000	30,000	30,000 e/	30,000 e/	30,000
Mexico	41,800	51,430	48,016	47,522	51,685 4/
Morocco (smectite)	17,223	24,425	27,650	21,956 r/	30,665 4/
Pakistan	13,415	12,307	14,659	15,565	15,288 4/
Senegal (attapulgite) e/	100,000	80,000	80,000	80,000	80,000
South Africa (attapulgite)	14,318	9,349	7,830 r/	7,067 r/	7,337 4/
Spain (attapulgite) e/	94,000	90,000	90,000	90,000	90,000
United Kingdom 5/	143,000	140,000	140,000 e/	140,000 e/	140,000
United States 6/	2,600,000	2,370,000	2,420,000	2,560,000	2,910,000 4/
Total	3,570,000 r/	3,350,000 r/	3,380,000	3,510,000 r/	3,870,000

See footnotes at end of table.

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TABLE 26--Continued
FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes centrally planned economy countries and former such countries, some of which presumably produce fuller's earth, but for which no information is available. Table includes data available through August 21, 2001.
3/ In addition to the market economy countries listed, France, India, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.
4/ Reported figure.
5/ Salable product.
6/ Sold or used by producers.

TABLE 27
KAOLIN: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Algeria	25,000 e/	18,533	13,640	16,833 r/	11,616 4/
Argentina	64,241	47,365	46,832	45,000	45,000
Australia (includes ball clay) e/	210,000	220,000	180,000 r/	200,000 r/	220,000
Austria (marketable) e/	60,000	60,000	60,000	50,000 r/	50,000
Bangladesh e/ 5/	7,000	7,200	7,500	7,700	7,900
Belgium e/	300,000	300,000	300,000	300,000	300,000
Bosnia and Herzegovina e/	3,000	3,000	3,000	3,000	3,000
Brazil (beneficiated)	1,057,671	1,165,047 r/	1,373,892 r/	1,516,700 r/	1,500,000
Bulgaria e/	115,000	115,000	110,000	110,000	110,000
Burundi e/	1,000	1,000	1,000	800	800
Chile	13,452	14,238	11,530	4,361 r/	6,445 4/
Colombia (includes common clay)	3,957,000	8,040,000	8,000,000 e/	8,000,000	8,000,000
Czech Republic	2,798,000	2,982,000	3,049,000	5,183,000 4/	5,200,000 4/
Denmark (sales) e/	3,000	3,000	2,500	2,500	2,500
Ecuador	86,541	7,345	7,000 e/	7,000	7,000
Egypt	258,725	258,869	285,497	290,000	290,000
Eritrea	2,620	4,670 e/	3,809	474 r/	393 4/
Ethiopia	1,428 r/	3,512 r/	378 r/	681 r/	1,654 4/
France (marketable)	326,000	332,000	330,000 e/	325,000	300,000
Germany	1,794,000	1,800,000 e/	1,800,000 e/	1,800,000	1,800,000
Greece	60,453	60,000	60,000 e/	60,000	60,000
Guatemala e/	109	110	110	110	100
Hungary (processed) e/	5,000	6,000	7,000	7,000	7,000
India:					
Processed	183,268	175,000	148,000	150,000	160,000
Salable crude	557,778	402,000 r/	540,000 r/	520,000	530,000
Indonesia	15,000 e/	1,956	8,567	21,389	22,000
Iran	350,000	510,000	582,485 r/	837,277 r/	800,000
Israel	14,000 r/	16,000 r/	27,000 r/	27,300 r/	26,700
Italy, kaolinitic earth e/	10,000	9,000	9,000	9,000	10,000
Japan	141,230	110,915	83,257	53,092	26,000 4/
Jordan	47,500	57,255	78,000	34,040	36,795 4/
Kazakhstan e/	40,000	50,000	60,000	70,000	70,000
Kenya e/	595 4/	500	500	500	500
Korea, Republic of	2,501,600	2,688,489	2,259,809	1,858,359	2,098,499 4/
Madagascar e/	34 r/ 4/	166 r/ 4/	160 r/	110 r/	115
Malaysia	324,578 r /	221,769 r/	198,930 r/	208,187 r/	225,139 4/
Mexico	253,602	235,278	339,013	489,993	532,268 4/
New Zealand	26,325	21,874	26,000	25,000	25,000
Nigeria	102,078	100,000 e/	110,000 e/	110,000	110,000
Pakistan	54,860	66,235	70,777	64,692	49,574 4/
Paraguay	66,500	66,700	66,600 r/	66,600 r/	66,500
Peru	14,295	7,875	4,968 r/	1,332 r/	6,165 4/
Poland (washed)	71,700	83,600	82,450 e/	88,792 r/	99,382 4/

See footnotes at end of table.

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TABLE 27--Continued
KAOLIN: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Portugal e/	177,423 4/	180,000	180,000	175,000 r/	175,000
Romania	45,199	29,169	24,724	25,456 r/	19,007 4/
Russia (concentrate)	50,000	50,000	50,000	40,600 r/	45,000
Serbia and Montenegro: e/					
Crude	55,000	55,000	75,092 4/	40,321 4/	40,000
Washed	5,000	5,000	7,000	3,000	4,000
Slovakia	23,240	24,000 e/	28,000	22,000 r/	25,000
Slovenia: e/					
Crude	10,000	10,000	10,000	10,000	10,000
Washed	7,000	7,000	4,000	4,000	4,000
South Africa	191,900 r/	164,400 r/	138,300 r/	122,400 r/	98,897 4/
Spain (marketable), crude and washed e/ 6/	315,000	315,000	300,000	320,000 r/	365,000 4/
Sri Lanka	7,700	15,800 r/	11,110 r/	12,573 r/	12,230 4/
Sweden e/	460	450	450	450	440
Taiwan e/	100,000	100,000	70,000	70,000	68,000
Thailand (beneficiated)	553,770	306,835 r/	266,455 r/	113,005 r/	201,226 4/
Turkey	449,561	472,646	403,733	400,000	400,000
Ukraine e/	250,000 r/	250,000 r/	201,670 r/ 4/	221,526 r/	225,000
United Kingdom (sales) 7/	2,281,000	2,400,000 e/	2,391,595	2,303,607	2,420,000 4/
United States 8/	9,120,000	9,280,000	9,640,000	9,160,000	8,800,000
Uzbekistan e/	5,500,000	5,500,000	5,500,000	5,500,000	5,500,000
Venezuela	7,542	5,000	4,000 r/	12,000 r/	--
Vietnam e/	1,000	1,100	1,100	1,100	1,200
Total	35,100,000 r/	39,400,000 r/	39,700,000 r/	41,100,000 r/	41,200,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through August 21, 2001.

3/ In addition to the countries listed, China, Morocco, and Suriname also may have produced kaolin, but information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Data for year ending June 30 of that stated.

6/ Includes crude and washed kaolin and refractory clays not further described.

7/ Dry weight.

8/ Kaolin sold or used by producers.

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COAL COMBUSTION PRODUCTS

By Rustu S. Kalyoncu

Domestic survey data and tables were prepared by Rustu S. Kalyoncu, physical scientist.

The working definition for solid materials resulting from the combustion of coal has been evolving. Environmental regulators first used the term coal combustion wastes. Later, the term coal combustion byproducts gained popularity. Lately, coal combustion products (CCPs) has become a household term for those in the power industry, the ash marketers, and most users of these materials. The solids included in CCPs are fly ash, bottom ash, boiler slags, and flue gas desulfurization (FGD) material (synthetic gypsum). Fly ash is the fine fraction of the CCPs that is carried out of the boiler by the flue gases. Almost all fly ash is captured by dust collecting systems, such as electrostatic precipitators. Bottom ash is defined as the large ash particles that accumulate at the bottom of the boiler. Boiler slag is the molten inorganic material that is collected at the bottom of the boilers and discharged into a water-filled pit where it is quenched and removed as glassy particles resembling sand.

Electricity accounts for more than one-third of the primary energy used in the United States, and more than one-half of the Nation's electricity is generated by burning coal. Coal burning, combined with pollution control technologies, generates large quantities of CCPs. During 2000, about 860 million metric tons (Mt) of coal was burned, and about 98 Mt of CCPs was generated by the electric utilities.

In addition to the ash, sulfur in flue gases emitted from fossil-fuel-burning electricity-generating plants is also a concern for the environment. The majority of electric power utilities, especially in the Eastern and Midwestern States, use high-sulfur bituminous coal. Increased use of high-sulfur coal has contributed to an acid rain problem in North America. To address this problem, the U.S. Congress passed the Clean Air Act Amendments of 1990 (CAAA '90) (Public Law 101-549) with stringent restrictions on sulfur oxide emissions. The sulfur dioxide (SO_2) reduction provisions of the CAAA, which would be implemented in a two-phase plan to be completed by 2010, forced the electric utilities to find ways of reducing SO_2 emissions. A number of utilities have switched to alternative fuels, such as low-sulfur coal or fuel oil, as partial or temporary solutions to the problem. A significant number of electric utilities still using high-sulfur coal have installed FGD units.

FGD units remove SO_2 from flue gas but, in doing so, generate large quantities of synthetic gypsum (FGD material), which is a mixture of gypsum, calcium sulfite ($CaSO_3$), fly ash, and unreacted lime or limestone. A number of powerplants convert the $CaSO_3$ to calcium sulfate by forced oxidation and take appropriate measures to reduce the other impurities in the FGD material to produce synthetic gypsum that exceeds the specification for wallboard manufacture. Wallboard plants, recently constructed adjacent to such electric utilities, use the FGD gypsum from those electric utilities. The FGD material adds to the accumulation of already high levels of CCPs. About 23 Mt of FGD material was produced in 2000, and about 4.5 Mt (20%) was used mostly for wallboard manufacture.

FGD issues affect, directly or indirectly, coal, gypsum, lime, limestone, and soda ash producers. Increased commercial use of FGD products represents an economic opportunity for high-sulfur coal producers and the sorbent industry (especially lime and limestone). Today, synthetic gypsum competes directly with natural mined gypsum as raw material for wallboard manufacture.

The value of CCPs is well established by research and commercial practice in the United States and abroad. As engineering materials, these products can add value while helping conserve the Nation's natural resources.

Fly ash represents a major component (58%) of CCPs produced, followed by FGD material (24%), bottom ash

Coal Combustion Products in the 20th Century

The history of coal combustion products (CCPs) began 2000 years ago with the use of fly ash by the Romans in the construction of aqueducts and coliseums. The first research on fly ash was reported in the Proceedings of the American Concrete Institute in 1937, which introduced the term "fly ash" to the literature. Chicago Fly Ash Co., formed in 1946, was the first to market fly ash as a construction material for manufacturing concrete pipe. The U.S. Bureau of Reclamation used fly ash on a large scale in the construction of the Hungry Horse Dam in Montana in 1949. Six other dams were constructed during the 1950s using fly ash concrete. Initial markets for fly ash were as a portland cement extender and as an enhancer of the qualities of concrete to meet new postwar requirements.

In 2000, almost 1 billion metric tons of coal was burned, which generated 120 million metric tons of CCPs. Electric utilities alone burned over 860 million tons of coal and generated over 98 million tons of CCPs, almost 30 million tons of which was used in a number of areas, primarily in cement and concrete (11.7 million tons), structural fills (4.9 million tons), waste stabilization (2.0 million tons), road base/subbase (1.2 million tons), and mining (1.1 million tons) applications. Innovative high-volume applications are being developed. In 2000, CCPs were used as a raw material in numerous products ranging from wallboard to bowling balls.

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(15.5%), and boiler slag (2.5%). Among the major CCP components, fly ash and FGD materials boast the highest use rate at about 32% of the amount produced.

Legislation and Government Programs

The Resource Conservation and Recovery Act (RCRA), enacted in 1976, has been the primary statute governing the management and use of CCPs. CCPs have been the subject of investigation by the U.S. Environmental Protection Agency (EPA), which published its regulatory determination on wastes from the combustion of fossil fuels in May (U.S. Environmental Protection Agency, 2000). The agency concluded that CCPs do not pose sufficient danger to the environment to warrant regulations under section 3001(b)(3)(C) of subtitle C of the RCRA. However, the EPA also determined that national regulations under subtitle D of the RCRA are warranted for CCPs when they are disposed of in landfills or surface impoundments. Furthermore, possible modifications to existing regulations established under the authority of the Surface Mining Control and Reclamation Act are warranted when they are used to fill surface or underground mines. A detailed review of Government regulations was made in an earlier publication (Kalyoncu, 2000).

The EPA, however, remains particularly critical of State programs and is concerned that Federal Government oversight is needed to ensure that mine filling is done appropriately to protect human health and the environment, particularly since mine filling is a recent but rapidly expanding use of coal combustion wastes (U.S. Environmental Protection Agency, 2000, p. 32231).

Production

Table 1 summarizes the historical production and use of CCPs for the years 1996 through 2000. A small, steady increase in CCP production rates through 2000 is apparent. In 1999, it was predicted that fly ash, bottom ash, and boiler slag production could be expected to remain flat in the near future, as no significant increase in the use of coal was planned for electric power generation. An unexpected jump in petroleum prices, however, may well change the Nation's energy equation in favor of increased coal use. An increase in ash generation can be expected with increased coal burning. The commencement of phase two of the CAAA in January 2000 is expected to contribute to a significant increase in synthetic gypsum generation in the years ahead. The energy policies of the new administration, which call for increased use of fossil fuels, especially use of coal in electric power generation, gives an additional reason to anticipate increases in the generation of CCPs.

Tables 2 through 4 list the domestic production and consumption data for 2000. Table 2 lists the total quantities of CCPs (dry and ponded), whereas tables 3 and 4 summarize the dry and ponded CCP data, respectively.

Graphic representations of CCP data are shown in figures 2 through 9. Figures 2 and 3 show historical CCP production and use data, respectively. Total CCPs production and use data for 2000 are presented in figure 4. Figure 5 depicts production by CCP type and region. Figures 6 through 9 show leading uses for fly ash, bottom ash, boiler slag, and FGD material, respectively.

Consumption

The components of CCPs have different uses because they have distinct chemical and physical properties; each one is suitable for a particular application. CCPs are used in cement and concrete, mine backfill, agriculture, blasting grit, and roofing applications. Other current uses include waste stabilization, road base/subbase, and wallboard production (synthetic gypsum). Potential FGD gypsum uses also include applications in subsidence and acid mine drainage control and as fillers and extenders.

Total CCP use in 2000 decreased to 28.59 Mt from 30.00 Mt in 1999, a 4.7% decrease. Fly ash, bottom ash, and boiler slag all showed slight decreases in use, whereas FGD material recorded an 8.7% increase over the 1999 figure (table 1).

Domestic CCP consumption data from 1996 to 2000 are summarized in figure 3. Figures 6 through 9 summarize the use data for individual CCP types. Among the CCPs, fly ash was used in the largest quantities and found the widest range of applications, with about 60% of annual consumption used in various structural applications. Use in cement and concrete production tops the list of leading fly ash applications with more than 50%, followed by structural fills and waste stabilization (figure 6).

Structural fill and road base/subbase applications are major bottom ash uses. About 65% of bottom ash is used in road base/subbase, structural fill, and snow and ice control (figure 7). Minor uses include concrete, mining applications, and cement clinker raw feed.

Bottom ash can also be used as fine aggregate in asphalt paving mixtures. Some bottom ash is sufficiently well graded that pavements containing bottom ash alone can meet gradation requirements. Bottom ash containing pyrites or porous particles is not suitable for use in hot mix asphalt mixtures, where strict gradation requirements exist. It is used more commonly in cold-mix emulsified asphalt mixtures, where gradation requirements and durability are not critical as in hot mix surface mixtures.

Owing to its considerable abrasive properties, boiler slag is used almost exclusively in the manufacture of blasting grit. Use as roofing granules is also a significant market area. Blasting grit and roofing granules make up almost 90% of boiler slag applications (figure 8).

Boiler slag can also be used as fine aggregate, especially in hot mix asphalt owing to its superior hardness, affinity for asphalt, and its dust-free surface, which aids in asphalt adhesion and resistance to stripping. Since boiler slag exhibits a uniform particle size, it is commonly blended with other aggregates for use in asphalt mixtures.

Wallboard manufacture (more than two-thirds of the total), concrete, mining applications, and structural fill account for the bulk of FGD product uses (figure 9). Structural fill and concrete account for a majority of other uses of FGD material. Agricultural uses account for only 2.3% of total FGD material use. However, potential FGD material use in agriculture

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exceeds even its use in wallboard manufacture. This potential, however, needs to be realized through demonstration studies.

The 1999 annual survey of CCPs elaborated on the unprecedented demand for wallboard experienced across the United States (Kalyoncu, 2001). In an attempt to meet the increased demand, the wallboard industry moved aggressively to increase the manufacturing capacity through new plant construction and succeeded in doing so. With the signs of recent downturn in the economy, however, demand for wallboard will not keep its current levels. U.S. Gypsum Co. closed several plants in Plaster City, PA; Gypsum, OH; and in Plasterco, VA. Georgia Pacific Corp. closed two of its Grand Rapids, MI, wallboard plants. Closures of old and openings of new plants by the industry resulted in net increase in wallboard production capacity, but owing to decline in demand for wallboard, the existing plants were operating below their production capacity (Olson, 2001). The plant closures are not expected to affect synthetic gypsum use by the wallboard industry, because most of the facilities using synthetic gypsum are recently built modern plants. Companies are closing old, antiquated plants that used natural gypsum and are more likely to close similar old plants designed to use natural gypsum as raw material. This will undoubtedly affect the natural gypsum industry.

World Review

Efforts were made to compile world production and consumption data for the year 2000. However, only 1999 data were provided by the respondents. Data were obtained from major European and Asian countries, including India, the Republic of Korea, China, and Russia. Table 5 summarizes partial world CCP statistics. In the table, data from 13 European Union countries are combined under the European Coal Combustion Products Association (ECOBA). ECOBA member countries are Belgium, France, Germany, Greece, Ireland, the Netherlands, Poland, Portugal, Spain, and the United Kingdom. ECOBA members account for over 90% of CCP production in Europe.

In 1999, the ECOBA profitably used 56% (31 Mt) of the 55.5 Mt of CCPs that its member countries generated compared with about 30% use in the United States. Over 18 Mt of the 37 Mt of fly ash produced was used (48% use rate). A slightly smaller fraction (44%) of bottom ash, 100% of boiler slag, and 87% of synthetic gypsum produced found beneficial uses (table 5). Raw material shortages and favorable state regulations account for the higher use rates of CCPs in Europe. As in the United States, ECOBA members used CCPs in a number of applications, with concrete leading the way at 37%, followed by portland cement manufacture with 31% and road construction with 21%; other uses made up the remainder (11%). Among the individual countries contacted, Canada, India, Israel, Japan, and South Africa reported partial CCP production and use data. Canada used about 1.9 Mt (27%) of 7 Mt of CCPs produced, whereas coal-burning electric utilities in India generated about 90 Mt of CCPs in 1999, of which about 13% (11.7 Mt) was used. The remainder was disposed of in wet ponds. In Japan, 1999 figures were 9.1 Mt and 7.65 Mt for production and use, respectively. These figures translate into an 84% use rate for Japan. The high disposal cost of CCPs in Japan ($100.00 per metric ton) make alternative uses economically viable (Mark Early, Barlow Junker Pty Ltd., oral commun., 2001).

Large volume CCP use in India, China, and the Republic of Korea is an environmental and economic necessity owing to the planned increase in coal-fired powerplants to meet future electricity needs and the high ash contents of coal burned. Current burning of coal, containing 40% to 45% mineral matter, generates 90 million metric tons per year (Mt/yr) of CCPs in India, most of which is disposed of in wet ponds in the vicinity of the plants. The situation in the Republic of Korea is even more serious owing to the fact that the Republic of Korea burns more coal for electricity production than any other country in the world. Coal in the Republic of Korea also contains high fractions of mineral matter, which results in the generation of CCP quantities four times that of the United States (table 5) (Ji-Young Ryu, Korea Electric Power Corporation, oral commun., 2001).

Current Research and Technology

Research and development activities have focused on improving FGD processes and finding new applications for CCPs, especially the FGD product. Japanese and West European researchers have led much of the activity in the development of new FGD technologies. Electric utilities in these countries have no room for the disposal of the products from the current FGD processes and are forced to find better solutions to flue gas emission problems. Research efforts emphasize the development of technology that requires less space for installation and yields smaller quantities of products than the well established methods using lime or limestone as sorbents.

Research and development efforts in FGD have been directed, for the most part, toward either decreasing the quantities of the reaction products or increasing their economic value to upgrade them from waste products to resources.

Consol Energy Corp. successfully manufactured aggregates from CCPs using a pelletization process it developed (Aggregates Manager, 2000). Fly ash and synthetic gypsum are combined by disk pelletization with moderate-temperature curing to form aggregates. If commercialized, such manufactured aggregates may eventually play an important role in the 2-billion-ton-per-year aggregates market.

In order to reduce nitrogen oxides emissions to meet the requirements of the CAAA's restrictions on nitrogen oxide (NO_x) emissions, many electric utilities installed no-NO_x burners. No-NO_x burners, however, lead to a significant increase in the unburned carbon content of fly ash, in certain cases exceeding 10%. High carbon content renders fly ash unsuitable for cement and concrete applications, which account for the bulk of fly ash use. Excess unburned carbon in concrete-containing fly ash cement reduces the freeze-thaw resistence of concrete by capturing the air entraining agents that are used to modify the microstructure by introducing controlled porosity.

Researchers at the Pennsylvania State University have developed a method to economically separate unburned coal from fly ash (Skillings Mining Review, 1999). It appears that

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the unburned carbon separated from the fly ash is suitable for manufacturing activated carbon, which is used in water treatment and gas purification processes. These carbon products have a significant market with 350,000 metric tons per year sold. The unburned carbon, separated from fly ash, does not need cleaning or grinding, nor does it need heating to remove volatiles. While anthracite, which is currently used as the precursor in the manufacture of activated carbon, sells for about $50.00 per metric ton, the unburned-carbon in fly ash can be separated at $10 to $15 per metric ton, and the fly ash can be sold to concrete or cement producers.

Reports of research and development results during the past two decades indicate that an increase in the development of uses for CCPs will happen in small steps. At the 14th International Symposium on Management and Use of Coal Combustion Products, held in San Antonio, TX, in January 2001, researchers from industry, academia, and Federal and State Governments made presentations that covered a range of topics from characterization to applications of CCPs in landfills, agriculture, mine backfilling, acid mine abatement, manufacture of building blocks, and recovery of high-value rare-earth metals. The proceedings of the 14th symposium contain 82 papers, presented in 13 sessions (American Coal Ash Association, 2001).

As construction materials, CCPs add to and enhance the chemical durability while reducing costs. In agricultural applications, gypsum-rich products provide sulfur needed by plants. In waste stabilization, pozzolanic properties of these products can immobilize nuclear and toxic compounds and allow the disposal of such compounds in a safe manner. Substantial benefits to the society will include conservation of land and natural resources and reduction in CO_2 emissions.

There are a number of technical, economic, institutional, and legal barriers to the use of large quantities of CCPs. Technical and economic barriers are not mutually exclusive, in that technological advancements usually result in economic feasibility. Principal technical barriers include issues related to CCP production, specifications and standards, materials characterization, product demonstration and commercialization, and user-related factors.

Economic barriers to increased CCP use can be key among all factors affecting byproduct use. With proper economic incentives other barriers to increased use of CCPs can be overcome. For coal-burning electric utilities, the revenues from the sale of CCPs is often insignificant. The high cost of transporting the low unit-value CCPs and competition from locally available natural materials pose two of the most important economic barriers.

Among the institutional and legal barriers are the lack of knowledge of potential ash uses, the sporadic data on environmental and health effects, the compositional inconsistencies in the products, belief that other raw materials are readily available, the lack of State guidelines, and the viewpoint of the industry that EPA regulations and procurement guidelines are too complicated and rigid rather than being general guidelines for use.

A subcommittee of the American Society for Testing and Materials Committee E-50 on Environmental Assessment, on which the U.S. Geological Survey (USGS) is represented, was recently formed to address the question of standards and definitions of coal and CCP-related terms. The latest draft of the definitions document was evaluated by subcommittee members, and recommendations were submitted to the committee for action in 2001. This draft calls for the change of CCPs to coal combustion byproducts (CCBs), to iterate the ideal definition of a product, which is the principal reason for a process. It is argued that coal is burned to produce energy, not ash. Therefore, energy is the product of coal burning process; anything else is a byproduct.

The perception of potential harm to the environment leads to government policies that translate into rigid barriers to the use of CCPs. The recent decision by the EPA to list CCPs under subsection D of the RCRA, which classifies CCPs as potentially hazardous in mine reclamation and backfill applications, is a formidable barrier to the use of CCPs in mine applications. Researchers and marketing professionals have been making efforts to remove such barriers to the use of these materials.

Concerned industry and government representatives, scientists, and engineers have formed a number of national and international organizations to address the removal of barriers to use of CCPs. Some of the most prominent are the American Coal Ash Association (ACAA), the recently formed Coal Ash Resources Research Consortium (CARRC), the Center for Applied Energy Research , the Coal Combustion Byproducts Recycling Consortium (CBRC), the Coal Combustion Byproduct Information Network Steering Committee (CCBINSC), and a number of State organizations.

The ACAA, founded in 1968 by the coal-burning electric utilities and based in Alexandria, VA, has as its mission the advancement of the management and use of CCPs in ways that are technically sound, economically feasible, and environmentally safe. It serves producers and marketers of CCPs, coal producers, allied trade groups, consultants, and academic institutions. Since its establishment, the ACAA has helped shape the technical, educational, government relations, communications, and marketing efforts funded primarily by membership dues and income from educational programs and sales.

The CARRC, housed at the University of North Dakota Energy and Environmental Research Center, is an international organization of industry and government representatives and scientists working together to advance CCP use. The CARRC works to solve CCP-related problems and promote environmentally safe and technically sound use of CCPs. Over the years, the CARRC has contributed to the generation of scientific and engineering information on CCPs, the development of characterization methods, and demonstration of new CCP uses (University of North Dakota Energy and Environmental Research Center, [undated], What's CARRC?, accessed October 23, 2001, at URL http://www.undeerc.org/carrc/html/Whatscarrc.html).

The CBRC is a program of the National Mine and Land Reclamation Center, located at West Virginia University, in cooperation with the U.S. Department of Energy Technology Laboratory. The objective of the CBRC is to develop technologies for coal-burning utilities to solve problems related to production and use of CCPs. The CBRC has thus far sponsored two major CCP use demonstration projects and has

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published a request for proposals for a third project (Combustion Byproducts Recycling Consortium, [undated], Home page, accessed October 23, 2001, at URL http://cbrc.nrcce.wvu.edu/cbrchome.htm).

The CCBINSC, established in 1997, is a voluntary planning group made up of representatives from a number of Federal and State Government agencies, including the USGS, and research organizations to compile and disseminate the information available through a comprehensive web site. Since its establishment, the committee organizes and conducts a CCB forum every other year. An extensive source of technical inventories, current research activities, and governmental and legal developments on CCP issues is available on the U.S. Department of the Interior's Office of Surface Mining web site (CCB Information Network, [undated], Steering Committee, accessed October 23, 2001, at URL http://www.mcrcc.osmre.gov/ccb/Steering.htm).

A number of major symposia and conferences are held annually or every other year on the use and management of CCPs. Among such significant periodically held events are the International Ash Utilization Symposium, sponsored and run by the University of Kentucky; the ACAA's International Symposium on Management and Use of CCPs, held on odd-number years; the CCB's forum, sponsored and held by the CCBINSC on even-number years; and the annual International Pittsburgh Coal Conference, organized and run by the University of Pittsburgh.

Outlook

Two principal factors that will affect the size of the coal market and, therefore, quantities of CCPs generated are market deregulation and emissions regulations. Market deregulation will encourage electric utilities to search for the lowest cost fuel, and that will most probably be coal. On the other hand, there is the need to comply with phase two of the CAAA. Phase two of the CAAA, implemented in January 2000, capped powerplant SO_2 emissions nationally at 7.72 Mt/yr. As of January 2000, there were about 10 Mt of SO_2 allowances available for sale to noncompliant plants. The allowances were accrued during phase one of the CAAA. Quick disappearance of these allowances will force utilities to switch to clean fuels or to retrofit powerplants with FGD units.

Increases in the production of fly ash and bottom ash will be proportional to the increase in coal use for electric power production. However, there may be a significant rise in the FGD material owing to the implementation of phase two of the CAAA. Only 10% of the utilities were affected by the first phase of the implementation of the law. A noticeable increase in the quantities of FGD material produced will become apparent in the coming years. Currently, power generation systems with more than 10,000-megawatt (MW) capacity support FGD units, and limestone units with more than 6,000-MW capacity and lime units with nearly 4,000-MW capacity are under construction. Moreover, the construction of limestone systems with 7,000-MW capacity and lime systems with 6,000-MW capacity are in the planning stage. When operational, these systems are expected to more than triple the quantity of FGD material to about 75 Mt/yr from the current level of 24 Mt/yr. With continued installation of FGD units, FGD material production could double the amount of CCPs currently being generated. Combined with the potential effect of future EPA rulemaking, this presents a formidable challenge to electric utilities and CCP-user industries.

To answer the challenge, utilities will continue to look for pollution-prevention technologies that will yield lesser quantities but purer and higher value FGD material. An example of such a trend is seen at Basin Electric Cooperative's Dakota Gasification plant in Beulah, ND, where a wet-ammonia-based FGD unit is used to remove SO_2 in the combustion of otherwise nonsalable fuels derived from gasification of lignite. The resulting ammonium sulfate is sold and used as a sulfur blending stock in fertilizer production (William Ellison, Ellison Consultants, oral commun., 1999).

References Cited

Aggregates Manager, 2000, State by State: Aggregates Manager, v. 4, no. 7, p. 15.

American Coal Ash Association, 2001, Proceedings of the 14th International Symposium on Management and Use of Coal Combustion Products (CCPs), San Antonio, TX, January 22-26, 2001: Alexandria, VA, American Coal Ash Association, 19 p.

Kalyoncu, R.S., 2000, Coal combustion products, *in* Metals and Minerals: U.S. Geological Survey Minerals Yearbook 1998, v. I, p. 19.1-19.19.

———2001, Coal combustion products, *in* Metals and Minerals: U.S. Geological Survey Minerals Yearbook 1999, v. I, p. 19.1-19.14.

Olson, D.W., 2001, Gypsum—2000 annual review: U.S. Geological Survey Minerals Industry Surveys, October, 13 p. [Prepared for publication in 2000 U.S. Geological Survey Minerals Yearbook.]

Skillings Mining Review, 1999, Penn State researchers study use of coal byproducts: Skillings Mining Review, v. 88, no. 13, March 27, p. 9.

U.S. Environmental Protection Agency, 2000, Notice of regulatory determination on wastes from the combustion of fossil fuels: Federal Register, v. 65, no. 99, p. 32214-32237.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Gypsum. Ch. in Mineral Commodity Summaries, annual.

Gypsum. Mineral Industry Surveys, annual and monthly.

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TABLE 1
HISTORIC COAL COMBUSTION PRODUCT PRODUCTION AND USE

(Thousand metric tons)

	1996	1997	1998	1999	2000
Fly ash:					
Production	53,900	54,700	57,200	56,900	57,100
Use	14,700	17,500	19,200	18,900	17,600
Percent use	27.50	32.10	33.60	33.20	30.90
Bottom ash:					
Production	14,600	15,400	15,200	15,300	15,400
Use	4,430	4,600	4,760	4,930	4,460
Percent use	30.40	30.20	31.30	32.10	29.00
Boiler slag:					
Production	2,360	2,490	2,710	2,620	2,430
Use	2,170	2,340	2,170	2,150	2,120
Percent use	92.30	94.10	80.10	81.80	87.00
FGD material: 1/					
Production	21,700	22,800	22,700	22,300	23,300
Use	1,500	1,980	2,260	4,030	4,380
Percent use	6.96	8.67	10.00	18.10	18.80
Total CCPs:					
Production	92,400	95,400	97,800	97,100	98,200
Use	22,800	26,500	28,400	30,000	28,600
Percent use	24.90	27.80	29.00	30.80	29.10

1/ FGD: Flue gas desulfurization.

Source: American Coal Ash Association.

TABLE 2
TOTAL COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000 1/

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD 2/ material	Total CCPs
Production	57,100	15,400	2,440	23,300	98,200
Use:					
Agriculture	13	4	--	69	86
Blasting grit-roofing granules	--	133	1,900	--	2,030
Cement clinker raw feed	1,030	158	--	--	2,290
Concrete-grout	9,600	381	(3/)	318	10,300
Flowable fill	632	10	16	30	688
Mineral filler	108	93	11	(3/)	212
Mining applications	1,050	333	--	166	1,550
Road base-subbase	1,100	759	(3/)	85	1,940
Snow and ice control	3	755	53	--	811
Soil modification	102	25	--	--	127
Structural fills	2,370	1,230	32	496	4,130
Wallboard	--	--	--	3,020	3,020
Waste stabilization-solidification	1,800	32	--	19	1,850
Other	413	571	89	173	1,250
Total	18,200	4,480	2,110	4,380	24,800
Individual use percentage	31.90	29.20	86.50	18.80	29.10
Cumulative use percentage	31.90	31.30	33.10	29.70	NA

NA Not available. -- Zero.
1/ Total CCPs include categories I and II, dry and ponded respectively.
2/ FGD: Flue gas desulfurization.
3/ Less than 1/2 unit.

Source: American Coal Ash Association.

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TABLE 3
DRY COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD material 1/	Total CCPs
Production	42,600	9,420	756	18,400	71,200
Use:					
Agriculture	13	4	--	66	83
Blasting grit-roofing granules	--	102	610	--	712
Cement clinker raw feed	818	142	--	--	960
Concrete-grout	9,240	276	--	317	9,830
Flowable fill	274	10	--	1	285
Mineral filler	106	51	11	(2/)	168
Mining applications	682	258	--	164	1,100
Road base-subbase	1,070	508	--	85	1,660
Snow and ice control	3	489	12	--	504
Soil modification	71	22	--	--	93
Structural fills	2,320	483	32	496	3,330
Wallboard	--	--	--	2,160	2,160
Waste stabilization-solidification	1,800	27	--	19	1,850
Other	68	336	28	170	602
Total	16,500	2,710	693	3,480	19,900
Individual use percentage	38.60	28.70	91.70	19.00	NA
Cumulative use percentage	38.60	36.80	37.60	32.80	NA

NA Not available. -- Zero.
1/ FGD: Flue gas desulfurization.
2/ Less than 1/2 unit.

Source: American Coal Ash Association.

TABLE 4
PONDED COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD material 1/	Total CCPs
Production	14,500	5,920	1,680	4,900	22,100
Use:					
Agriculture	--	--	--	3	3
Blasting grit/roofing granules	--	31	1,290	--	1,320
Cement clinker raw feed	211	15	--	--	226
Concrete-grout	362	105	(2/)	1	468
Flowable fill	358	(2/)	16	29	403
Mineral filler	2	42	--	--	44
Mining applications	363	75	--	2	440
Road base-subbase	30	251	(2/)	--	281
Snow and ice control	--	266	41	--	307
Soil modification	30	4	--	--	34
Structural fills	51	743	(2/)	--	794
Wallboard	--	--	--	857	857
Waste stabilization-solidification	--	5	--	--	5
Other	346	235	61	3	645
Total	1,750	1,770	1,410	895	4,940
Individual use percentage	12.10	29.90	84.10	18.30	NA
Cumulative use percentage	12.10	17.30	22.40	21.60	NA

NA Not available. -- Zero.
1/ FGD: Flue gas desulfurization.
2/ Less than 1/2 unit.

Source: American Coal Ash Association.

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TABLE 5
WORLD COAL COMBUSTION PRODUCTS PRODUCTION AND USE, 2000

(Thousand metric tons)

Country	Fly ash	Bottom ash	Boiler slag	FBC ashes	Other	SDA product	FGD gypsum	Total	Percent use
European Coal Combustion Products Association:									
Production	37.14	5.62	2.42	0.99	0.24	0.52	7.57	54.50	XX
Use:									
Cement raw material	3.74	0.05	--	--	--	--	--	3.79	6.8
Blended cement	1.93	--	--	0.01	--	--	--	1.94	3.5
Concrete addition	5.44	0.02	0.16	0.03	--	--	--	5.65	10.2
Aerated concrete blocks	0.67	0.07	--	--	--	--	--	0.74	1.3
Nonaerated concrete blocks	0.59	1.23	--	--	--	--	--	1.83	3.3
Lightweight aggregate	0.24	0.08	--	--	--	0.01	--	0.32	0.6
Bricks and ceramics	0.07	--	--	--	--	--	--	0.07	0.1
Grouting	0.52	--	0.16	--	--	--	--	0.68	1.2
Asphalt filler	0.19	--	--	0.05	--	--	--	0.24	0.4
Subgrade stabilization	0.33	0.03	--	--	--	--	--	0.36	0.7
Pavement base course	0.21	0.33	1.25	--	--	--	--	1.78	3.2
General engineering fill	1.30	0.37	--	--	--	0.03	--	1.70	3.1
Structural fill	1.39	0.18	--	--	--	--	--	1.57	2.8
Soil amendment	(1/)	--	--	--	--	0.08	--	0.09	0.2
Infill	1.38	--	--	0.36	--	0.32	--	2.05	3.7
Blasting grit	--	--	0.73	--	--	--	--	0.73	1.3
Plant nutrition	--	--	0.04	--	--	0.04	--	0.07	0.1
Set retarder for cement	--	--	--	--	--	--	0.47	0.47	0.8
Projection plaster	--	--	--	--	--	--	0.62	0.62	1.1
Plaster boards	--	--	--	--	--	--	4.04	4.04	7.3
Gypsum blocks	--	--	--	--	--	--	0.24	0.24	0.4
Self leveling floor screeds	--	--	--	--	--	--	1.25	1.25	2.3
Other uses	0.20	0.13	0.09	(1/)	0.24	--	--	0.65	1.2
Total	18.17	2.50	2.42	0.45	0.24	0.47	6.62	30.86	55.6
Landfill, reclamation, restoration	15.43	2.07	--	0.39	--	0.04	0.42	18.35	33.0
Temporary stockpile	0.72	0.03	--	--	--	--	0.45	1.19	2.1
Disposal	3.81	1.06	--	0.15	--	0.01	0.09	5.12	9.2
Utilization rate in percent	48	44	100	45	100	91	87	XX	XX
Canada:									
Production	5.00	1.60	--	--	--	--	0.42	7.02	XX
Use	1.10	0.20	--	--	--	--	0.57	1.87	27.00
India:									
Production	--	--	--	--	--	--	--	90.00	XX
Use	--	--	--	--	--	--	--	11.70	13.00
Israel:									
Production	--	--	--	--	--	--	--	1.20	XX
Use	--	--	--	--	--	--	--	1.05	87.00
Japan:									
Production	6.50	1.20	--	--	--	--	1.50	9.10	XX
Use	5.25	0.90	--	--	--	--	1.50	7.65	84.00
South Africa:									
Production	1.70	--	--	--	--	--	--	1.70	XX
Use	--	--	--	--	--	--	--	--	NA

NA Not available. XX Not applicable. -- Zero.
1/ Less than 1/2 unit.

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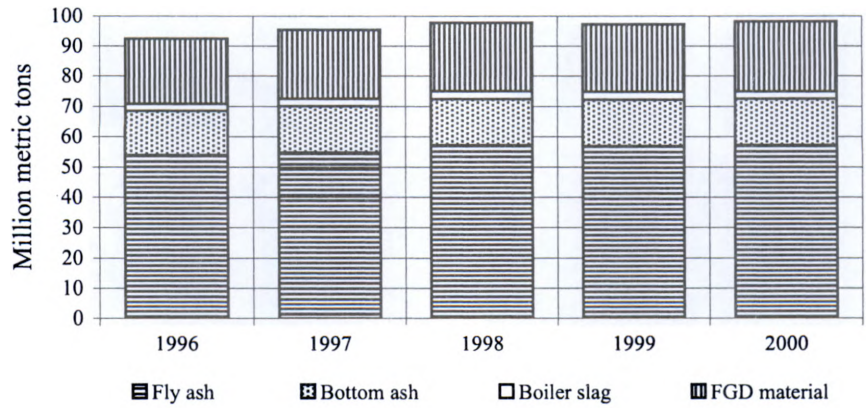
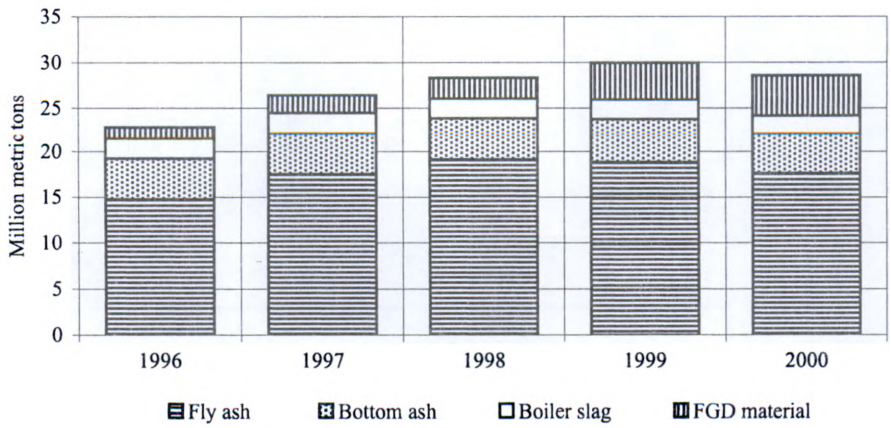
FIGURE 1
ACAA REGIONS OF THE UNITED STATES

FIGURE 2
HISTORIC COAL COMBUSTION PRODUCT PRODUCTION DATA, 1996-2000



Source: American Coal Ash Association

FIGURE 3
HISTORIC COAL COMBUSTION PRODUCT USE DATA, 1996-2000



Source: American Coal Ash Association

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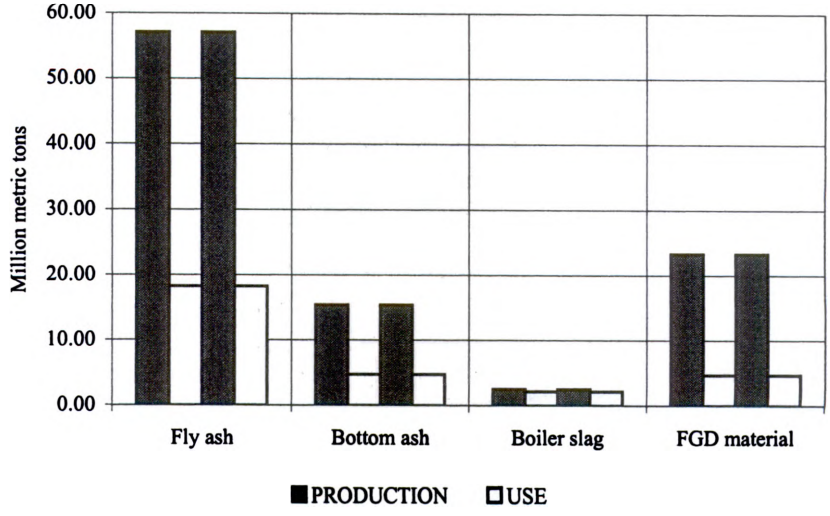
FIGURE 4

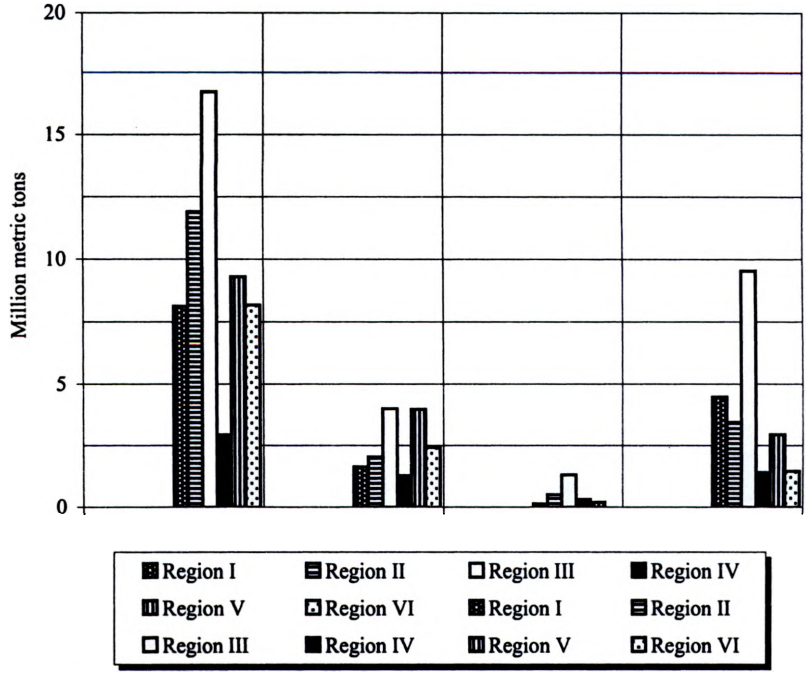
COAL COMBUSTION PRODUCT PRODUCTION AND USE FOR THE UNITED STATES, 2000



Source: American Coal Ash Association

FIGURE 5

COAL COMBUSTION PRODUCT PRODUCTION BY TYPE AND REGION, 2000



Source: American Coal Ash Association

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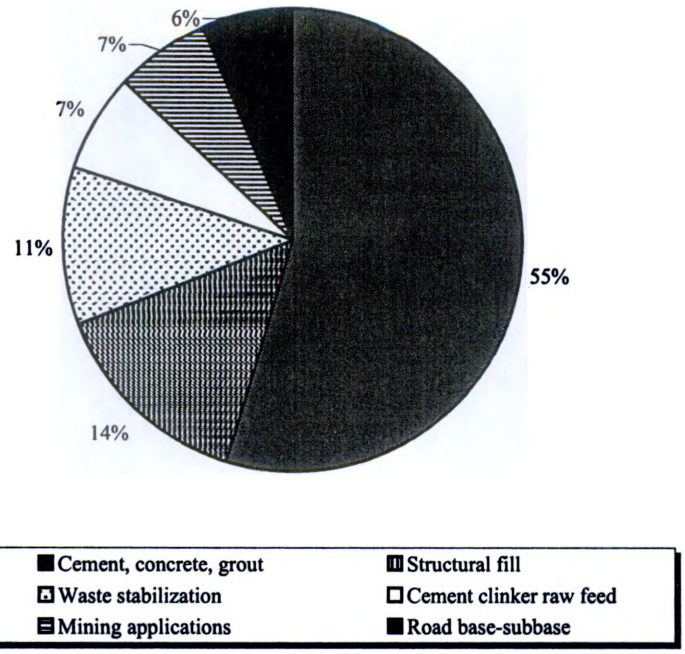
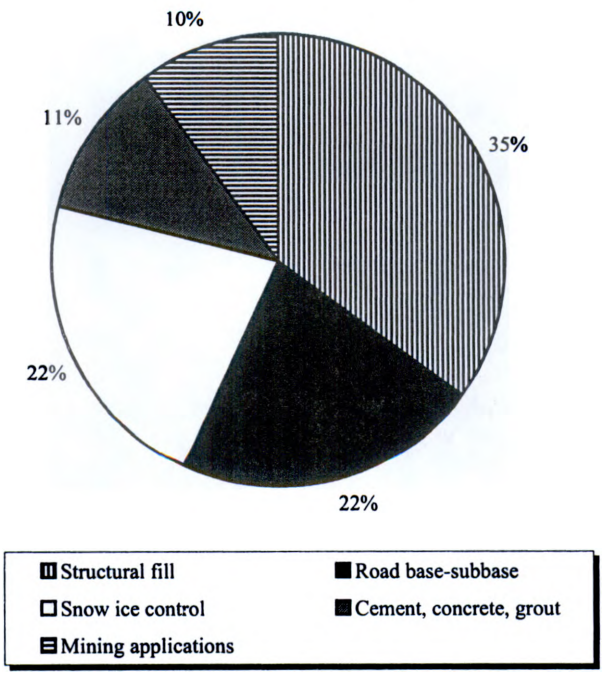
FIGURE 6
LEADING FLY ASH USES, 2000



Source: American Coal Ash Association

FIGURE 7
LEADING BOTTOM ASH USES, 2000



Source: American Coal Ash Association

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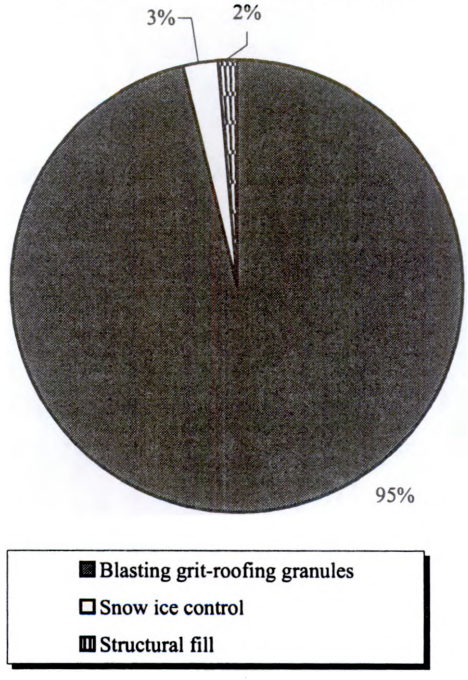
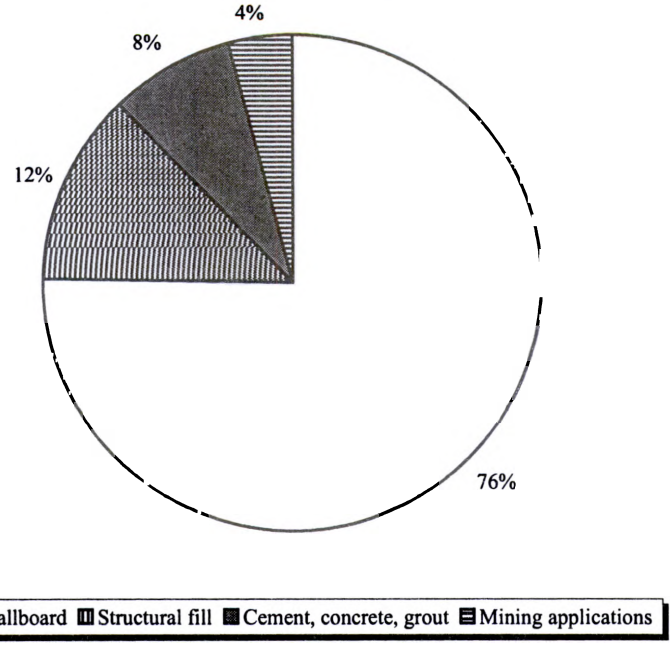
FIGURE 8
LEADING BOILER SLAG USES, 2000



Source: American Coal Ash Association

FIGURE 9
LEADING FGD MATERIAL USES, 2000



Source: American Coal Ash Association

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COBALT

By Kim B. Shedd

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production tables were prepared by Linder Roberts and Glenn J. Wallace, international data coordinators.

Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The United States remained the world's largest consumer of cobalt. With the exception of negligible amounts of byproduct cobalt produced as intermediate products from some mining operations, the United States did not mine or refine cobalt in 2000. Since 1993, sales of excess cobalt from the National Defense Stockpile (NDS) have contributed to U.S. and world supplies.

World refined cobalt production increased in 2000. Some of the increase was from new operations in Australia and Uganda and some was from a net increase in production by established producers. During the year, several established producers announced that they would participate in evaluating the potential development of a "second wave" of nickel-cobalt laterite projects in Indonesia and the Philippines.

World demand for cobalt in 2000 was estimated to be similar or slightly less than that of 1999 (Cobalt Development Institute, 2001b). Weekly cobalt prices fluctuated within a narrower range than those during recent years. Annual average prices continued the downward trend that began in 1996.

Salient U.S. and world cobalt statistics for 2000 and the previous 4 years are listed in table 1. With the exception of prices and reported production from foreign countries, all quantity and value data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, held nine sealed-bid and three negotiated cobalt offerings during fiscal year 2000 (October 1, 1999, through September 30, 2000). During this period, the DNSC sold 2,720 metric tons (t) of cobalt cathode, granules, and rondelles valued at nearly $78 million (table 2). This represented all of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2000 Annual Materials Plan (AMP). As of the end of the fiscal year, 1,020 t of cobalt had been sold, but not shipped from the stockpile (U.S. Department of Defense, 2001). The AMP for fiscal year 2001 (October 1, 2000, through September 30, 2001) maintained the maximum allowable sale of cobalt at 2,720 t (Defense National Stockpile Center, 2000).

During 2000, DNSC held nine sealed-bid and three negotiated cobalt offerings and sold 3,080 t of cobalt cathode, granules, and rondelles valued at $89 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 9,300 t, all of which was authorized for eventual disposal.

Production

With the exception of negligible amounts of byproduct cobalt produced from mining operations in Missouri and Montana, the United States did not mine or refine cobalt in 2000 (Stillwater Mining Co., 2001, p. 9; U.S. Minerals Management Service, 2001, Federal onshore—Collections by commodity/revenue type, CY 2000 Jan-Dec, accessed May 22, 2001, at URL http://www.mrm.mms.gov/Stats/coll.htm).

Formation Capital Corp. of Vancouver, British Columbia, Canada, continued to study the feasibility of developing its 100%-owned Idaho Cobalt Project in the Idaho cobalt belt. The project was to entail underground mining of cobalt-copper-gold ores in Lemhi County, ID, producing concentrates by using mineral flotation, and then refining the cobalt concentrate by

Cobalt in the 20th Century

In 1900, the principal source of cobalt ore was New Caledonia. Although few statistics are available, world cobalt production was probably less than 180 metric tons contained cobalt. This cobalt was used mainly as cobalt oxide in the manufacture of pigments and decolorizers for china, pottery, porcelain, and glass. U.S. apparent consumption was less than 30 tons of cobalt oxide, containing approximately 20 tons of cobalt. Eighty-nine percent of the U.S. supply of cobalt oxide was imported, and 11% was produced domestically from a byproduct of smelting lead ores mined in Missouri.

In 2000, most cobalt was produced as a byproduct of copper or nickel. World production of refined cobalt was 35,200 tons of contained cobalt. The principal sources of cobalt-bearing ores were Australia, Canada, Cuba, the Democratic Republic of the Congo [Congo (Kinshasa)], Morocco, New Caledonia, Russia, and Zambia. Cobalt was used in many diverse commercial, industrial, and military applications. The largest use of cobalt was in superalloys, which were used to make parts for gas turbine engines. Cobalt was also used to make magnets; corrosion- and wear-resistant alloys; high-speed steels; cemented carbides (also called hardmetals) and diamond tools; catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, and inks; ground coats for porcelain enamels; pigments; battery electrodes; steel-belted radial tires; airbags in automobiles; and magnetic recording media. The U.S. apparent consumption of cobalt was 11,700 tons in 2000. With the exception of negligible amounts of byproduct cobalt produced as intermediate products from some mining operations, the United States did not mine or refine cobalt in 2000. U.S. cobalt supply consisted of imports, cobalt-bearing scrap, releases from industry stocks, and sales of excess cobalt metal from the National Defense Stockpile.

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using a pressure leaching process. In October, Formation Capital entered into an agreement with Sunshine Precious Metals, Inc. to purchase a hydrometallurgical refinery in Big Creek, ID. Formation planned to produce approximately 1,500 metric tons per year (t/yr) of cobalt as oxide, hydroxide, carbonate, and/or cathode, with initial production beginning in late 2003 (Formation Capital Corp., 2001a; b; c, p. 2-3, 8-10). Mining in the Idaho Cobalt Belt dates back to the late 1800s and extended until 1959, when the Blackbird Mine in Cobalt, ID, closed. Noranda Mining Inc. of Salt Lake City, UT, considered reopening the mine in the late 1970s to early 1980s, and Blackbird Metals Inc., a New York-based corporation, planned to buy and reopen the mine in the late 1980s to early 1990s. In both cases, the companies did not pursue their plans and the mine remains inactive.

During the year, U.S. Cobalt Inc. of Denver, CO, worked toward developing the Madison Mine, near Fredericktown, MO. Past production from the mine, which occurred intermittently from the mid-1800s to 1961, yielded cobalt, copper, lead, and nickel. U.S. Cobalt was considering two options for the project—building a fully integrated mine-mill-refinery on the Madison property or sending ores from the mine to be custom milled at a nearby facility, and then shipping the resulting cobalt-nickel concentrate to a smelter or refinery. In October, the company released a new resource estimate for the mine. Using a cobalt equivalent cutoff grade of 0.20%, the measured plus indicated resource was 6.6 million metric tons, grading 0.306% cobalt, 0.743% copper, and 0.470% nickel (U.S. Cobalt Inc., 2001, p. 10-13).

PolyMet Mining Corp. of Golden, CO, continued to study the NorthMet deposit under a lease agreement with USX Corp. of Pittsburgh, PA. NorthMet occurs in the Duluth Complex of northeastern Minnesota, a large layered mafic intrusion that contains, in order of relative abundance, copper, nickel, cobalt, silver, platinum-group metals, and gold. In August, PolyMet released the results from a continuous, fully integrated pilot-plant study of the pressure oxidation leaching process chosen to treat sulfide concentrates from the deposit. Leaching efficiencies for all metals except gold were equal to or greater than those obtained from laboratory scale testing of the process performed in 1999. In December, PolyMet announced that drilling results on the property indicated continuity and consistency in grade between the main ore body and a northeast extension of mineralization. PolyMet planned to complete a prefeasibility study by the end of the first quarter of 2001 (PolyMet Mining Corp., 2000a, b).

U.S. processors made cobalt chemicals and cobalt metal powders from cobalt metal and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. Five of the seven cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products, a division of Union Minière, Inc., made cobalt metal powder from cobalt metal at its Laurinburg, NC, plant. Osram Sylvania Inc. made cobalt metal powder from scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

Consumption

U.S. apparent consumption for 2000, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 9% higher than that calculated for 1999 (see table 1). In 2000, an increase in shipments of cobalt from the NDS was greater than the decreases in net imports and cobalt recovered from scrap.

U.S. reported consumption for 2000 was 3% higher than that for 1999. As compared with that of 1999, metallurgical industries consumed 8% more cobalt and the total reported cobalt consumption in chemical uses was 7% lower. Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as superalloy, magnetic alloy, and cemented carbide producers. For this survey, nearly 90 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

Prices

U.S. spot prices for cathode (minimum of 99.8% cobalt), as reported by Platt's Metals Week, fluctuated between $13 per pound and $18 per pound. The lowest prices were reported in February, July, and December, and the highest prices were reported at the end of April-beginning of May and the end of September. Platt's average annual U.S. spot cathode price for 2000 was $15.16 per pound, down by 11% from that of 1999. This price has steadily declined since 1995, when it was $29.21 per pound (table 1).

Trends in Platt's prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were more or less parallel to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was $13.74 per pound, and the annual average of weekly prices for Russian cobalt was $12.98 per pound.

Sales prices for 99.8% cobalt cathode reported by WMC Ltd. at its Internet web site provided some market transparency and became a benchmark for cobalt prices (Metal Bulletin, 2000d; Ryan's Notes, 2000). The trend in these prices was similar to that of Platt's U.S. spot cathode prices. WMC's lowest sales price was $12.40 per pound in late July and its highest sales price was $17.50 per pound in late September.

In October, OM Group Inc. announced that it had established an Internet web site for cobalt sales. OM Group's Internet sales were limited to spot sales of grade B cobalt briquettes, which contained a minimum of 99.8% cobalt. Sale prices during November and December ranged from $12.40 per pound to $13.00 per pound.

Foreign Trade

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States.

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In 2000, net import reliance as a percent of apparent consumption was 78%. Because there was no measurable U.S. primary cobalt production in 2000, this indicates that 78% of U.S. cobalt supply was from imports and stock releases and 22% was from scrap, which would have been generated domestically or imported.

As shown in tables 4 and 5, in 2000, the United States imported 8% more cobalt than it did in 1999. Eight countries supplied 88% of U.S. imports of unwrought cobalt and cobalt in chemicals. Finland was the leading supplier, followed by Norway, Russia, the Democratic Republic of the Congo [Congo (Kinshasa)], Canada, Belgium, Brazil, and Zambia. Compared with those of 1999, cobalt imports from Belgium, Brazil, Canada, Finland, and Russia increased and imports from Congo (Kinshasa), Norway, and Zambia decreased.

In 2000, the United States imported 214 t, gross weight, of unwrought cobalt alloys valued at $6.4 million. Five countries supplied more than 95% of these materials—Congo (Kinshasa) (45%), Sweden (16%), Belgium (15%), Japan (14%), and the United Kingdom (6%). The United States imported 550 t, gross weight, of cobalt matte, waste, and scrap, valued at $4.1 million. Seven countries supplied more than 90% of these materials—the United Kingdom (43%), France (13%), Germany (11%), Canada (10%), Japan (6%), and Argentina and Belgium (5% each). The United States also imported 359 t, gross weight, of wrought cobalt and cobalt articles valued at $18.8 million. The leading suppliers of these materials were Japan (30%); the United Kingdom (28%); Germany (11%); and Belgium, France, and the Netherlands (5% each).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased by 70% compared with those of 1999. As listed in table 6, 87% of the cobalt metal and chemical exports was shipped to nine countries—Belgium, Canada, France, Germany, Japan, Mexico, the Netherlands, the Republic of Korea, and the United Kingdom. The remainder was shipped to 41 other countries.

Exports also included 971 t, gross weight, of wrought metal and cobalt articles valued at $37.8 million. Eighty-five percent of these materials was sent to eight countries—Germany (24%), the United Kingdom (23%), Japan (10%), India (9%), Belgium and Canada (6% each), the Republic of Korea (4%), and Netherlands (3%). The remainder was shipped to 35 other countries.

World Review

World refined cobalt production increased in 2000 as compared with that of 1999. Some of the increase in production was from new producers in Australia and Uganda and some was from a net increase in production by established producers. Refinery capacity by country is listed in table 7. Plants that reprocessed refined cobalt, that used secondary materials (scrap) as their main source of feed, or that produced a cobalt product that required further refining were not included.

Australia.—QNI Pty. Ltd. processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,520 t of cobalt as cobalt oxide hydroxide, approximately the same amount as the 1,539 t produced in 1999 (Cobalt Development Institute, 2001b). In May, QNI purchased a 40% direct joint-venture interest in the Ravensthorpe nickel project from Comet Resources Ltd. The project involved building a front-end pressure acid leaching plant at Ravensthorpe on the southern coast of Western Australia. Lateritic ore from Ravensthorpe would be processed at the plant to produce an intermediate nickel-cobalt hydroxide, which would then be shipped to Yabulu for refining. During the year, the QNI-Comet joint venture performed laboratory scale and continuous pilot-plant testwork and made revised resource estimates for several of the deposits at Ravensthorpe. The front-end engineering and design phase of the project was expected to be completed during the second quarter of 2001 (Comet Resources Ltd., 2000). QNI planned to expand the Yabulu refinery to accommodate the increase in feed material. Future production from Ravensthorpe was estimated at approximately 35,000 t/yr of nickel and 1,300 t/yr of cobalt. The Yabulu refinery capacity might be increased to 65,000 t/yr of nickel and 3,000 t/yr of cobalt (Billiton plc, 1999).

WMC produced an estimated 800 t of cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia (WMC Ltd., 1999). The mixed sulfide was refined in Norway by Falconbridge Ltd. under a tolling agreement and the cobalt cathode was offered for sale by WMC on its Internet web site.

Outokumpu Australia Pty. Ltd. produced nickel concentrates from its Black Swan nickel operations in Western Australia. Nickel concentrates from this operation and from WMC's Mount Keith operation, containing an estimated 500 t of cobalt, were exported to Finland for treatment at the Harjavalta refinery (Matheson, 1999).

Anaconda Nickel Ltd. produced 925 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure acid leaching operation east of Leonora in Western Australia (Cobalt Development Institute, 2001b). The company cited engineering and materials problems as the causes for delays in commissioning the plant and ramping up production to the stage I design capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt. Anaconda hoped to reach stage I capacity by the second half of 2001. During the year, Anaconda worked on a rolling expansion of the Murrin Murrin plant to the stage II capacity of 108,000 t/yr of nickel and 7,600 t/yr of cobalt. The company also studied the feasibility of developing its Mount Margaret project, northwest of Murrin Murrin. Anaconda's long-term (10 year to 15 year) plan was to produce more than 20,000 t/yr of cobalt from three nickel provinces—Murrin Murrin, the Mount Margaret and Murchinson deposits north of Murrin Murrin, and Cawse and Broad Arrow south of Murrin Murrin (Anaconda Nickel Ltd., 2000, 2001; Masterman, 2000; Reuters Ltd., 2000a).

Centaur Mining & Exploration Ltd. produced 998 t of cobalt contained in cobalt sulfide from its Cawse nickel-cobalt laterite pressure acid leaching operation northwest of Kalgoorlie in Western Australia. This represented approximately 67% of the 1,500 t/yr of cobalt design capacity of the refinery. Centaur reported that to reduce operating costs, significant capital expenditure would be required to increase production through debottlenecking and expansion. The company was considering doubling the rate of feed through the autoclave in the refinery. In December, Centaur terminated a preliminary agreement with Anaconda Nickel to study the feasibility of expanding Cawse's refinery capacity and began discussions with other resource corporations regarding various options for the Cawse nickel operations (Centaur Mining & Exploration Ltd., 2000, 2001). Capacity and production of cobalt sulfide from Cawse are not

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included in tables 7 and 9 because the sulfide is an intermediate product that is upgraded by other cobalt refiners.

Preston Resources Ltd. produced 344 t of cobalt from its Bulong nickel-cobalt laterite pressure acid leaching operation east of Kalgoorlie in Western Australia. Approximately one-half of the cobalt, 170 t, was produced as cobalt cathode, and one-half was produced as an intermediate cobalt sulfide. Production did not reach the forecast levels of 8,100 t/yr of nickel and 700 t/yr of cobalt because of a series of technical problems with the refinery. Preston revised its best-case output to 9,000 t/yr of nickel and approximately 600 t/yr of cobalt. The company intended to work towards stabilizing output rather than expanding capacity as originally planned (Preston Resources Ltd., 2000a, b, 2001; Platts Metals Week, 2001a).

Titan Resources NL, West Perth, Western Australia, worked on developing a metallurgical process that used bacterial oxidation to recover base metals from sulfide ores. In August, Titan announced that it had held discussions with WMC regarding the possible application of the bioleaching process to WMC's currently [2000] subeconomic nickel resources (Titan Resources NL, 2000).

The Doe Run Co. of St. Louis, MO, a major lead producer, provided technical assistance to Compass Resources NL on its Browns lead-copper-cobalt-nickel sulfide project in Northern Territory. The Browns polymetallic deposit could be mined by using a conventional large-scale open pit method. Compass was considering a process that would entail grinding the ore, followed by bulk flotation to produce a mineral concentrate, which would be fed into a furnace where the lead would be fumed off and the cobalt, copper, and nickel would be converted to a sulfide matte. Metals in the matte would be dissolved by using an atmospheric acid leaching process. Copper and cobalt would be removed by using conventional solvent extraction-electrowinning (SX-EW) processes and nickel would be precipitated to a marketable product. Compass estimated an average cobalt production of 2,840 t/yr during the first 10 years of operation (Compass Resources NL, [undated], 2000 annual report—Operations review, accessed April 19, 2001, via URL http://Compassnl.com).

Black Range Minerals Ltd. completed a feasibility study on the Syerston nickel-cobalt-platinum laterite project approximately 400 kilometers northwest of Sydney in New South Wales. The study evaluated ore processing by pressure acid leaching, followed by SX-EW to produce nickel cathode and cobalt cathode. The proposed refinery was to have a design capacity of 20,000 t/yr of nickel and 5,000 t/yr of cobalt. Black Range evaluated several site locations for the refinery—Syerston, Broken Hill in western New South Wales, a site in China, and one in Malaysia—and determined that locating the refinery at one of the offshore sites would have the advantages of more attractive tax regimes and lower energy costs than those in Australia (Black Range Minerals Ltd., 2000, p. 4-5; 2001).

Belgium.—N.V. Union Minière S.A. converted cobalt metal, residues, and other cobalt-bearing materials into cobalt hydroxides, metal powders, oxides, and salts at its facilities in Olen. According to the Cobalt Development Institute (2001b), Union Minière's cobalt production increased by 17% in 2000, to 1,110 t, as compared with the 950 t produced in 1999. During the year, Union Minière began to build a new cobalt oxide plant in Olen to meet an anticipated increase in demand for raw materials for the rechargeable battery market (N.V. Union Minière S.A., 2001, p. 13).

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel-cobalt ore from Niquelandia, Goias State, as feed. Production during the past 2 years increased significantly as a result of a 1998 expansion to the refinery that increased the cobalt capacity to 800 t/yr. Niquel Tocantins planned to complete an additional increase in the refinery's capacity in 2002, which would result in an increase in cobalt production to 1,100 t/yr (Metal Bulletin, 2000f, 2001).

Canada.—Falconbridge Ltd. produced 667 t of cobalt in concentrate from its Sudbury, Ontario, mines and 289 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at its Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2000, this matte contained 1,792 t of cobalt; 49% of the cobalt originated from ores produced at company mines, and 51% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. Falconbridge's mine and smelter production were lower than those of 1999 as a result of a strike by production and maintenance workers at the company's Sudbury operations that began on August 1, 2000, and extended until February 20, 2001. During the strike, mining operations at Sudbury were reduced to 20% of normal production rates and smelting operations were reduced to 50% to 60% of prestrike rates (Falconbridge Ltd., 2001a, p. 17, 19).

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery from feed materials originating primarily from nickel mines in Thompson and Sudbury, respectively. In 2000, Inco produced 1,470 t of cobalt in Canada from both operations, a 4% increase from the 1,420 t produced in 1999 (Cobalt Development Institute, 2001b).

Inco's development of its Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador continued to be delayed by an impasse between the company and the Province of Newfoundland and Labrador. The Provincial Government refused to give approval for the project without a guarantee that the ores would be refined within the Province, and Inco refused to commit to building the refinery in the Province before it was proven to be technically and economically feasible. During the year, Inco continued with exploration activities at Voisey's Bay to further define the deposit and explore new targets. Inco also continued research and development work on a proprietary hydrometallurgical process for Voisey's Bay sulfide concentrates (Inco Ltd., 2001, p. 18, 43).

The Sherritt International Corp.-General Nickel Co. S.A. joint venture's refinery in Fort Saskatchewan, Alberta, produced a record 2,855 t of cobalt in 2000, a 3% increase from the 2,770 t of cobalt in 1999. The increase in production was attributed to an increase in the cobalt content of feed used by the refinery (Sherritt International Corp., 2001, p. 20). Most of the feed was in the form of nickel-cobalt mixed sulfides from the joint venture's operations at Moa Bay, Cuba. As a result of a U.S. embargo on imports of products originating from Cuba, nickel and cobalt produced by Sherritt cannot be sold to U.S. customers.

Canmine Resources Corp. worked on planning, maintenance, engineering, and basic principal testing of processes for the hydrometallurgical refinery it purchased in late 1999. The North Cobalt, Ontario, refinery was to have an initial output of 300 t/yr of cobalt in carbonate or oxide. Canmine planned to begin production by processing feed materials produced by

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other companies, including a stockpile of cobalt-silver bearing materials, which Canmine purchased from Agnico-Eagle Mines Ltd. in January 2000. Once details on financing had been finalized, Canmine planned to announce timelines for construction, commissioning, and ramp up of production at the refinery. Future expansions to 1,000 t/yr or 2,000 t/yr of cobalt were being considered, depending in part on the development of Canmine's Werner Lake cobalt project and Maskwa nickel project in southwestern Ontario-southeastern Manitoba (Canmine Resources Corp., 2000, 2001).

China.—An estimated 1,200 t of cobalt metal and chemicals was produced from domestic and imported raw materials (Cobalt Development Institute, 2001b). The largest Chinese cobalt producers were Jinchuan Non-Ferrous Metals Corp. and Ganzhou Cobalt & Tungsten Co., Ltd. Jinchuan produced cobalt cathode and downstream products from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchuan, Gansu Province. Ganzhou produced cobalt metal powders and salts at Ganzhou, Jiangxi Province. From the 1980s until 1999, this company imported and refined all of the cobalt concentrates produced in Morocco (see "Morocco" section of this report). Cobalt metal powder, oxides, salts, and other products were produced by a number of smaller producers and cobalt processors in China (Cie. de Tifnout Tiranimine, 2001; Song, 2001, p. 3-16).

Congo (Kinshasa).—In March, the Ministry of Mines issued a decree that revoked the contract that established Central Mining Group Corp. S.P.R.L., a joint venture between La Générale des Carrières et des Mines (Gécamines), the Government of Congo (Kinshasa), and Ridgepointe Overseas Developments Ltd. The joint venture had been established in 1998 to manage and rehabilitate the copper-cobalt operations in Gécamines' Central Group. As a result of its revocation, the assets of the joint venture were returned to Gécamines (Metal Bulletin, 2000b).

Gécamines and L'Enterprise Generale Malta Forrest S.P.R.L. produced copper-cobalt concentrates from the Luiswishi Mine, which were purchased by OM Group, Inc. for its Kokkola refinery in Finland under a long-term supply contract. The concentrates produced from Luiswishi were estimated to contain approximately 5,000 t/yr of cobalt (OM Group, Inc., 2001, p. 7).

During the fourth quarter, Gécamines, OM Group, and S.A. Groupe George Forrest completed construction of the Big Hill smelter at Lubumbashi and began producing a cobalt-copper alloy, which was shipped to OM Group's Kokkola refinery. The smelter used slag stockpiled at Lubumbashi as feed. The stockpile was expected to supply the smelter for 20 years at a production rate of 5,000 t/yr of contained cobalt (OM Group, Inc., 2001, p. 3, 7).

Congo Mineral Development Ltd. (CMD), a joint venture between America Mineral Fields Inc. and Anglo American plc, continued to work on the Kolwezi tailings project. During the year, CMD commissioned a pilot plant in Johannesburg, South Africa, to determine a suitable flow sheet for the SX-EW process and began collecting baseline data for the environmental impact study. CMD and Gécamines agreed to implement the project in two phases. In phase one, approximately 3 million metric tons per year (Mt/yr) of tailings would be treated to produce as much as 42,000 t/yr of copper and 7,000 t/yr of cobalt cathode. In phase two, the amount of tailings treated would be doubled. A full feasibility study on the project was to begin after CMD obtained the necessary decrees from the President of Congo (Kinshasa). Upon receipt of these decrees, ownership of the Kolwezi tailings project would be transferred to a new company, KMT Sarl, which would be 60% owned by CMD and 40% owned by Gécamines. CMD had not yet received the decrees by yearend (America Mineral Fields Inc., 2001, p. 2-4, 7).

In late 1999, Melkior Resources Inc. and Gécamines agreed to create La Société Minière de Kabolela et Kipese (SMKK) to mine the Kabolela copper-cobalt and Kipese cobalt-gold-platinum deposits near the city of Likasi. SMKK was 60% owned by Melkior and 40% owned by Gécamines. By the end of 2000, the Kabolela Mine was in production and ore treated at the Kakanda concentrator yielded 27 t of cobalt in concentrates (Melkior Resources Inc., 2000a, b).

The rebellion by military factions dissatisfied with the Government of Congo (Kinshasa) that began in August 1998 continued into early 2001. Political uncertainty resulting from the ongoing civil war delayed the progress of the following joint-venture projects with Gécamines: First Quantum Minerals Ltd.'s copper-cobalt tailings projects at Kolwezi and Likasi; International Panorama Resource Corp.'s Kakanda copper-cobalt tailings project; Iscor Ltd.'s rehabilitation of the Kamoto Mine; and Tenke Mining Corp.'s development of copper-cobalt deposits at Tenke and Fungurume. Also delayed was the Mudima consortium's feasibility study on rehabilitating the mines and plants in Gécamines' Kolwezi Group West (First Quantum Minerals Ltd., 2001, p. 29; Tenke Mining Corp., 2001, p. 16; International Panorama Resource Corp., 2001; Iscor Ltd., [undated], Mining—Base metals—Overview, accessed April 2, 2001, at URL http://www.iscorltd.co.za/mainframe.asp?imgname=01). East Asia Gold Corp. abandoned all rights to claims under agreements with Gécamines to study and develop the Mukondo and Luisha properties (East Asia Gold Corp., 2000).

Côte d'Ivoire.—Falconbridge increased its option to earn interest in the Touba-Biankouma nickel-cobalt laterite project in western Côte d'Ivoire to 85% (Falconbridge Ltd., 2001a, p. 28).

Cuba.—Moa Nickel S.A., which was part of the joint venture between Sherritt and General Nickel, mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 29,520 t of nickel and cobalt, a 9% increase from the 27,020 t produced in 1999. The increase in production was attributed to the systematic upgrading, rehabilitation, and debottlenecking activities that have been undertaken since the inception of the joint venture (Sherritt International Corp., 2001, p. 20). The mixed sulfides produced at Moa were sent to the joint venture's refinery in Fort Saskatchewan, Alberta, Canada. Nickel and cobalt of Cuban origin cannot be imported into the United States because of a U.S. embargo on imports from Cuba.

QNI Pty. Ltd., a subsidiary of Billiton plc, constructed a pilot plant in Perth, Western Australia, to test the pressure acid leaching of nickel-cobalt lateritic ores from its development projects, which included the San Felipe project in the Camaguey Province (Billiton plc, 2000). The San Felipe project was being investigated as a joint venture with Geominera S.A., Cuba's mining investment company.

Finland.—OM Group produced 7,700 t of cobalt in cobalt metal powders, briquettes, oxides, and salts, 24% more than the 6,200 t produced in 1999 (Cobalt Development Institute, 2001b). The Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, Congo (Kinshasa), Russia, the United States, and Zambia (OM Group, Inc., 2001, p. 7). OM

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Group planned to increase the refinery's capacity to 12,000 t/yr of cobalt (Metal Bulletin, 2000c).

In February, OM Group announced that it had reached an agreement to purchase the Harjavalta nickel refinery from Outokumpu Oyj. Outokumpu's nickel smelter was not included in the sale. Outokumpu planned to continue to smelt nickel concentrates for OM Group until its nickel mines were depleted, at which time Outokumpu would stop producing nickel. OM Group planned to find a new nickel-cobalt feed source for Harjavalta (see "Indonesia" section of this report) and to develop the Harjavalta refinery to be more closely integrated with the Kokkola refinery. Historically most of the nickel and all of the cobalt from Harjavalta have been further processed at Kokkola (OM Group, Inc., 2000b; Outokumpu Oyj, 2000).

France.—The Eramet Group produced cobalt chloride at its refinery at Sandouville, near Le Havre. Feed for the refinery was nickel matte imported from Eramet subsidiary Le Nickel-SLN's Doniambo smelter in New Caledonia.

India.—Three companies refined cobalt from imported raw materials. Nicomet Industries Ltd. produced cobalt cathode and various salts at its plant in Cuncolim, Goa State; Rubamin Ltd. produced cobalt cathode and various salts at its plant in Vadodara, Gujarat State; and Conic Metals Ltd. produced cobalt sulfate and carbonate at its plant in Mumbai, Maharahtra State. In addition to this refinery production, cobalt metal powder was recovered from cemented carbide scrap by Sandvik Asia Ltd. at a pilot plant in Pune, Maharashtra State, and spent catalysts from plants producing terephthalic acid, dimethyl terephthalate, and OXO alcohols were reprocessed by more than a dozen small cobalt chemical processors (Cobalt Development Institute, 2001a).

Indonesia.—State-owned P.T. Aneka Tambang (Antam) exported lateritic nickel-cobalt ore to QNI's Yabulu refinery in Queensland, Australia. Several companies, including QNI, worked on projects to explore and develop Indonesia's nickel-cobalt laterite resources.

In February, OM Group and Weda Bay Minerals Inc. announced that they had signed an agreement to pursue the development of nickel-cobalt laterite deposits on Halmahera Island. Under the agreement, the companies would work together to complete a feasibility study to evaluate the production of an intermediate product containing approximately 30,000 t/yr of nickel and 3,000 t/yr of cobalt. OM Group would purchase all of the production from the first phase of the project as feed for the Harjavalta refinery (see "Finland" section of this report). By midyear, Weda Bay Minerals had started the drilling program and metallurgical test work for the feasibility study (OM Group, Inc., 2000a; Weda Bay Minerals Inc., 2000).

In July, Falconbridge and The Broken Hill Proprietary Co. Ltd. (BHP) announced that they had reached a tentative agreement to form a joint venture to study the feasibility of developing the Gag Island nickel-cobalt laterite project. Several matters had to be resolved before the agreement could be finalized, including clarification of commercial arrangements with Antam, clarification of the forestry classification on Gag Island, and resolution of the scope of work for the feasibility study. During the second half of the year, BHP held discussions with Falconbridge and Antam to resolve these issues (Broken Hill Proprietary Co. Ltd., 2000; BHP Ltd., 2001).

Japan.—Sumitomo Metal Mining Co., Ltd., produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel at its Niihama nickel refinery in Ehime Prefecture. Although not a large cobalt producing country, Japan was a significant cobalt consumer. The rechargeable battery industry was the largest consumer of cobalt in Japan. Manufacturers of cemented carbides, magnets, specialty steels and other alloys, and video tapes also consumed significant quantities of cobalt (Terada, 2000).

Mexico.—International Curator Resources Ltd. of Vancouver decided not to proceed with its Boleo copper-cobalt project near Santa Rosalia, Baja California. The decision was based on a combination of factors including the company's failure to persuade a partner to invest in the project, continued weak markets for the metals that would have been produced, and technical complexities of the deposit (International Curator Resources Ltd., 2001).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates, which in past years were all exported to China to be refined. In 1996, Cobalt Metallurgie Bou Azzer (CMBA) built a pretreatment plant at Bou Azzer and a refinery at Guemassa to produce cobalt cathode from tailings generated by past mining operations. In 1999, CMBA installed a second plant at Guemassa and began refining domestic concentrates in addition to tailings. As a result, exports of concentrates to China were expected to decrease and domestic production of refined cobalt was expected to increase. In 2000, CTT and CMBA merged to form one company under the name Cie. de Tifnout Tiranimine. CTT's production of refined cobalt increased by more than 150% to 1,200 t, from the 472 t produced in 1999 (M'Hamdi, 1996; Cobalt Development Institute, 2000; Metal Bulletin, 2000a; Cie. de Tifnout Tiranimine, 2001).

New Caledonia.—Lateritic nickel-cobalt ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Le Nickel-SLN's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride.

During the year, Inco continued a pilot-plant program to test its proprietary pressure acid leaching-solvent extraction process on nickel-cobalt laterites from the Goro deposit in southern New Caledonia. In December, Inco decided to proceed with the next stage of development of the Goro project. Major activities were to be as follows: to complete a bankable feasibility study; to arrange financing, select an engineering construction consortium, and prepare basic and detailed engineering plans for a commercial-scale refinery; to continue test work at the pilot plant; to complete discussions with the Government of New Caledonia regarding fiscal and regulatory arrangements and secure permits for construction and operation of the refinery; and to bring a partner into the project. Inco was planning to build a refinery with the capacity to produce 54,000 t/yr of nickel and 5,400 t/yr of cobalt. Production was forecast to begin in late 2004 or early 2005. The project was 85% owned by Inco, with the remainder owned by Bureau de Recherches Géologiques et Minières, a French Government agency (Inco Ltd., 2000; 2001, p. 17, 42-43).

Argosy Minerals Inc., in a joint venture with Société des Mines de la Tontouta, studied the feasibility of using pressure acid leaching technology to develop the Nakety nickel-cobalt laterite deposits on the east coast of New Caledonia. During the year, Argosy acquired the rights to develop the nearby Bogota mining concessions and worked towards bringing a major joint-venture partner into the project (Argosy Minerals Inc., 2001, p. 1-9).

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Norway.—In 2000, Falconbridge produced 3,431 t of cobalt at its Nikkelverk refinery, a 14% decrease from the 4,010 t produced in 1999. The decrease in production was attributed to a shortage of feed materials as a result of the strike by production and maintenance workers at company operations in Sudbury. In September, Falconbridge declared a full force majeure on cobalt shipments to the United States and Europe effective November 1 and on shipments to Japan effective December 1. This was amended to a partial force majeure on shipments to the United States and Europe for December. During 2000, 25% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada and 75% originated from custom feeds, defined as feeds that did not originate at Falconbridge mines. The custom feeds included matte from BCL Ltd. in Botswana, scrap, and intermediate materials (Reuters Ltd., 2000b; Falconbridge Ltd., 2001a, p. 18-19; 2001b, p. 15-16).

Papua New Guinea.—During the year, the Ramu nickel-cobalt laterite project received all the permits necessary for its development. On the basis of a feasibility study completed in 1998, the project was to use pressure acid leaching technology to produce 33,000 t/yr of nickel metal and 3,200 t/yr of cobalt as cobalt sulfate. At yearend the project was undergoing a change in ownership structure. Once all transactions were completed, Ramu's ownership was to be as follows: 47.95% Highlands Pacific Ltd., 47.05% Orogen Minerals Ltd., and 5% landowners. The partners planned to bring an additional equity partner into the joint venture (Highlands Pacific Ltd., 2000).

Philippines.—Lateritic nickel-cobalt ore from the Philippines was exported to QNI's Yabulu refinery for processing (Platt's Metals Week, 2000b).

In February, Impala Platinum Holdings Ltd. (Implats) of South Africa announced that it had concluded a memorandum of understanding with Philippine company Philnico Developments Ltd. regarding the Nonoc nickel-cobalt laterite project. Philnico planned to convert the mothballed nickel-cobalt plant at Nonoc in Surigao del Norte, Nonoc Island, from an ammonia leach process to a pressure acid leach process. Under the memorandum of understanding, Implats would fund a bankable feasibility study, and then assuming a positive outcome, invest an additional $75 million and contribute the nickel and cobalt assets of its base metals refinery in Springs, South Africa, to the project, in exchange for a 25% share. Mixed sulfides produced at Nonoc, containing approximately 41,000 t/yr of nickel and 4,000 t/yr of cobalt, would be sent to Springs to be refined. The capacity of the Springs refinery would be increased to handle the additional feed (Impala Platinum Holdings Ltd., 2000).

In April, Sumitomo Metal Mining Co. Ltd. agreed to begin a joint study with Rio Tuba Nickel Mining Corp. The study would examine the feasibility of using pressure acid leaching technology to produce a mixed nickel-cobalt intermediate from low-grade saprolitic and lateritic ores stockpiled at Rio Tuba's nickel mine on Palawan Island. Processing at a rate of 1 Mt/yr of ore was expected to yield 10,000 t/yr of nickel and 550 t/yr of cobalt (Metal Bulletin, 2000e; Reuters Ltd., 2000c).

Crew Development Corp., Vancouver, British Columbia, began a bankable feasibility study on a nickel-cobalt laterite deposit on Mindoro Island. Crew was considering building a refinery that would use pressure acid leaching to produce approximately 40,000 t/yr of nickel briquettes and 3,000 t/yr of cobalt briquettes. The project infrastructure would include an overland pipeline to transport ore slurry from the mine to the refinery, a port, power station, and village to support the operation. Following completion of the study, Crew planned to find a partner to develop the project (Crew Development Corp., 2000b).

Russia.—Nickel and cobalt production in Russia involved a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials were domestic nickel-copper sulfide and nickel-cobalt laterite ores and imported nickel- and cobalt-bearing secondary materials. Russia had the capacity to produce refined cobalt at four locations—RAO Norilsk Nickel refineries at Monchegorsk on the Kola Peninsula and Norilsk in Siberia, the Ufaleynickel Joint Stock Co. refinery at Verkhniy Ufaley in the Ural Mountains, and the Yuzhuralnickel Joint Stock Co. refinery at Orsk, also in the Ural Mountains (Roskill Information Services Ltd., 1995, p. 11-15).

Total Russian cobalt production was 22% higher than that of 1999 (Interfax Mining & Metals Report, 2001). Ninety-five percent of this production was by affiliated and dependent companies of RAO Norilsk Nickel. Norilsk Nickel's total production of cobalt in marketable products increased by 6.5% in 2000 compared with that of 1999. As compared with that of 1999, production of cobalt metal increased 24%, production of cobalt sulfate more than tripled, production of cobalt carbonate more than doubled, and production of cobalt oxides decreased (RAO Norilsk Nickel, 2001, p. 3, 20).

During the year, Norilsk Nickel approved a plan to develop the ore reserves and production capacity at the Pechenganickel Territorially Exclusive Structural Subdivision, which was a part of its Kola Mining and Metallurgical Co. subsidiary. Under the plan, production was expected to continue until 2015, which was a reversal of a previous plan to cease mining in that area by 2007 (RAO Norilsk Nickel, 2000).

Ufaleynickel commissioned a direct current arc furnace capable of producing 3,000 to 4,000 t/yr of granulated cobalt. The furnace was intended to replace an existing furnace and enable Ufaleynickel to produce granules in addition to the ingot it had been producing. The furnace's capacity was initially committed to tolling raw materials for Norilsk Nickel (Interfax Mining & Metals Report, 2000a; Metal Bulletin, 2000g).

In return for debt forgiveness, Yuzhuralnickel transferred its pyrometallurgical and hydrometallurgical plants to Yuzhpolimetall, a subsidiary controlled by gas provider Uraltransgaz. This left Yuzhuralnickel with nickel mining at the Buruktalskoye Mine in the Orenburg region and the Sakharinskoye Mine in the Chelyabinsk region and auxiliary and maintenance capacity. Late in the year, Yuzhuralnickel was considering toll-processing cobalt concentrates from Congo (Kinshasa) to improve the profitability of its cobalt production (Interfax Mining & Metals Report, 2000b, c, d).

South Africa.—Cobalt was mined as a byproduct from six platinum-group metal mines and as a coproduct from one nickel mine (Ngcai, 2001). Two South African companies produced refined cobalt as a byproduct of domestic platinum mining and refining. Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate at its refinery near Rustenburg, Northwest Province. Impala Platinum Ltd. produced cobalt metal powder at its base metals refinery near Springs, Gauteng Province. Impala was considering expanding the capacity of the Springs refinery to 60,000 t/yr of nickel and 4,200 t/yr of cobalt to accommodate an increase in feed that would result from the

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development of the Nonoc project in the Philippines (see "Philippines" section of this report).

During the fiscal year ending June 30, 2000, the Nkomati joint venture between Anglovaal Mining Ltd. (Avmin) and Anglo American produced 227 t of cobalt in concentrates from the Nkomati nickel sulfide mine in Mpumalanga Province. During the previous fiscal year, 211 t of cobalt in concentrates was produced. Avmin was considering expanding production from the mine (Anglovaal Mining Ltd., 2000).

Union Mineral Concentrators Pty., a Union Minière subsidiary, produced cobalt compounds from low-grade cobalt-containing residues in Roodepoort, near Johannesburg. During the year, Union Minière expanded the plant's capacity and broadened the range of compounds produced (N.V. Union Minière S.A., 2001, p. 14).

International Metal Processing (Pty.) Ltd. worked on a 3-year redevelopment and extension program to enhance its cobalt-copper-nickel refinery in Brakpan, Gauteng Provence. At the refinery, mineral concentrates were processed to produce cobalt cathode, metal powder, oxides and salts {International Metal Processing (Pty.) Ltd., [2000], Products produced, accessed May 8, 2001, at URL http://www.intmetals.com/Products.htm}.

Uganda.—Banff Resources Ltd., of Vancouver continued to focus its efforts on commissioning the Kasese cobalt refinery in southwestern Uganda. The refinery was designed to recover cobalt from stockpiled pyrite concentrates by using bacterial leaching followed by SX-EW. During the year, Banff made changes to the plant configuration to improve throughput, oxygen dispersal, and bacterial activity levels. By yearend, 420 t of cobalt cathode had been produced at Kasese, but throughput and production rates remained significantly below the engineered design capacity of 1,000 t/yr of cobalt (Banff Resources Ltd., 2001; Cobalt Development Institute, 2001b).

Zambia.—In March, the Government of the Republic of Zambia completed the privatization of Zambia Consolidated Copper Mines Ltd. (ZCCM) with the sale of ZCCM's remaining assets. Mopani Copper Mines plc, which was owned by the consortium of First Quantum and Glencore International AG (90%) and ZCCM (10%), acquired ZCCM's Mufulira division and certain assets of the Nkana division. The Mufulira division consisted of a copper mine, concentrator, smelter, and refinery. The Nkana assets included in the sale were the mine, concentrator, and cobalt plant, but not the smelter, copper refinery, and acid plant. Following acquisition, Mopani focused its efforts on restructuring, hiring, and training personnel and management, recapitalizing the operations, renegotiating supply contracts, purchasing spares and consumables, rehabilitating the plants and equipment, and underground mine development. Cobalt production from the Nkana cobalt plant was estimated to be 1,026 tons in 2000. The plant processed concentrates from Mopani's Nkana concentrator, the Chibuluma Mine, and on a tolling basis, Konkola Copper Mines plc operations (First Quantum Minerals Ltd., 2000; 2001, p. 15, 23; Cobalt Development Institute, 2001b).

Konkola Copper Mines, which was 65% owned by Zambia Copper Investments Ltd., a subsidiary of Anglo American, 20% by ZCCM, and 7.5% each by CDC Financial Services (Mauritius) Ltd. and the International Finance Corp., acquired the assets of ZCCM's Konkola division, including the Konkola Deep mining project; Nchanga division, with its Chingola refractory ore stockpiles; and Nampundwe pyrite mine. Following acquisition, Konkola Copper Mines began refurbishing the assets, revalidating the feasibility study on the Konkola Deep mining project, and seeking long-term financing for the project (Zambia Copper Investments Ltd., 2001). Konkola Copper Mines was also granted a 5-year option to acquire ZCCM's Nkana smelter, copper refinery, and acid plant. These assets were transferred to ZCCM (SmelterCo) Ltd., a wholly owned subsidiary of ZCCM, and were to be managed by Anglo American during the option period (Anglo American plc, 2000).

Chambishi Metals plc toll-refined copper-cobalt concentrates from mining operations in Zambia and heterogenite from Congo (Kinshasa) and produced 2,316 t of cobalt metal at its Chambishi cobalt plant. Production was impacted by lower than anticipated quantities and grades of feed materials. During the year, Chambishi worked on building a new smelter and matte leach facility at the plant. The new facility was designed to produce cobalt and copper from slag stockpiled at Nkana. Production from the new facility was expected to be 4,000 t/yr of cobalt and approximately 3,500 t/yr of copper. This would be in addition to the cobalt and copper produced by toll treating concentrates. At yearend, construction of the new facility was nearly completed and commissioning had begun. Production of the first salable metal from slag was planned for March 2001 (Anglovaal Mining Ltd., 2000, 2001; Cobalt Development Institute, 2001b).

Copper and cobalt production from Roan Antelope Mining Corp.'s Baluba and Luanshya mines decreased significantly from that of 1999 owing to financial problems that resulted in the Copperbelt Energy Corp. cutting the operation's power supply on several occasions. In late November, Roan Antelope was put under receivership because of unpaid debts. In early 2001, it was announced that the company's assets, including the Baluba and Luanshya mines, the Muliashi deposit, and approximately 10 Mt of smelter slag, would be put up for sale (Reuters Ltd., 2000d; Platts Metals Week, 2001b).

Approximately 100 t of cobalt was produced from the Chibuluma West Mine. The mine is 85% owned by Metorex Ltd., a subsidiary of Crew Development Corp., and 15% owned by ZCCM (Crew Development Corp., 2000a).

In late 1999, Orion Mining and Exploration Ltd. purchased and began rehabilitating the cobalt processing plant at Kabwe, which had been idle since 1998, when Colossal Resources Corp. ceased processing slag from the former ZCCM Nkana division. In 2000, Orion started processing slag imported from Congo (Kinshasa) and exporting the resulting cobalt alloy to China and Europe (Platt's Metals Week, 2000a, c).

Outlook

World cobalt production is expected to continue to increase. Production from new plants in Australia, Congo (Kinshasa), and Uganda is expected to ramp up during the next few years and output from some established refineries is likely to increase from 2000 levels. In addition, there are numerous projects in the prefeasibility, feasibility, or development stage in Africa, the Asia/Pacific region, and North America that include cobalt production. In nearly all of the proposed projects in the Asia/Pacific region, cobalt would be produced as a byproduct of nickel. Progress on these projects will depend more on the nickel market than on the cobalt market.

Another component of world supply is U.S. Government sales of cobalt from the NDS. Offers of NDS cobalt are

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expected to continue at the rate set each year under the AMP until the amount authorized for disposal has been sold. If the current (fiscal year 2001) AMP level of 2,720 t (6 million pounds) was maintained, and the amount of cobalt sold each year was close to the AMP level, then the NDS cobalt sales program could extend into 2004. However, the National Defense Authorization Act for Fiscal Year 1998 gave specific guidelines for cobalt disposals during fiscal years 2003 through 2007. During this 5-year period, cobalt disposals were required to result in receipts equal to the following amounts: $20 million during fiscal year 2003, $50 million during fiscal year 2004, $64 million during fiscal year 2005, $76 million during fiscal year 2006, and $34 million during fiscal year 2007. As part of the Act, the DNSC was not permitted to dispose of more than 6,350 t (14 million pounds) of cobalt during the 5-year period, and each year the DNSC would not be permitted to dispose of more cobalt than necessary to meet the specified dollar amount (U.S. Department of Defense, 2001, p. 37). Future cobalt prices and efforts by DNSC to meet, but not exceed, specific dollar amounts could impact the amount of cobalt available for sale each year.

Future demand will dictate how much additional cobalt the market can bear. Superalloys, which are used to make turbine parts for jet engines and land-based electrical power generators, continue to be the largest market for cobalt. Demand for jet aircraft and smaller power stations has been strong and is expected to trend upwards. The rechargeable battery industry has been rapidly increasing the amounts of cobalt it uses in recent years. Future growth in cobalt demand by this industry will depend on a combination of factors including the overall demand for batteries, the types of batteries produced, the availability and price of cobalt, and cobalt's image in terms of its toxicity, recyclability, security of supply, and stability of its price (Burstow, 2000; Gellens, 2000; Cundy, 2001; Falconbridge Ltd., 2001a, p. 32; Southwood and Gray, 2001).

Cobalt supply and demand are believed to be roughly in balance and are expected to remain in balance until 2004 or 2005 (Searle, 2001). The general consensus, however, is that the future increase in cobalt supply will be at a greater rate than the increase in demand, and that a resulting surplus will put downward pressure on cobalt prices. Several analysts have forecast that prices will drop to the $6 to $10 per pound range in 2 to 5 years (Burstow, 2000; Bacon and others, 2001, p. 9; Searle, 2001; Southwood and Gray, 2001).

References Cited

America Mineral Fields Inc., 2001, 2000 annual report: London, America Mineral Fields Inc., 31 p.

Anaconda Nickel Ltd., 2000, Quarterly report for the period ended June 30, 2000: Perth, Australia, Anaconda Nickel Ltd., 8 p.

———2001, Director's report for the half year ended 31 December 2000: Perth, Australia, Anaconda Nickel Ltd., 12 p.

Anglo American plc, 2000, Konkola Copper Mines transaction and disposal of shares in ZCCM: London, Anglo American plc news release, March 15, 2 p.

Anglovaal Mining Ltd., 2000, Avmin results to 30 June 2000: Johannesburg, Anglovaal Mining Ltd. press release, August 24, 5 p.

———2001, Results for the six months ended 31 December 2000: Johannesburg, Anglovaal Mining Ltd. press release, March 1, 3 p.

Argosy Minerals Inc., 2001, 2000 annual report: South Perth, Australia, Argosy Minerals Inc., 20 p.

Bacon, W.G., Ashok, D.D., and Rochon, B.A., 2001, Nickel outlook—The next ten years, *in* 250 years nickel...Issues for the future, Düsseldorf, Germany, May 6-12, 2001, Proceedings: Xanten, Germany, Heinz H. Pariser & Co. Alloy Metals and Steel Publications, 14 p.

Banff Resources Ltd., 2001, Banff Resources second quarter results: Toronto, Ontario, Canada, Banff Resources Ltd. press release, February 23, 8 p.

BHP Ltd., 2001, Quarterly report on exploration and development—September 2000-December 2000: Melbourne, Australia, BHP Ltd. news release, January 31, 11 p.

Billiton plc, 1999, QNI signs joint venture with Comet Resources on the Ravensthorpe nickel project: London, Billiton plc press release, November 11, 2 p.

———2000, Technical corner—Solvent extraction proves itself at Yabulu: Billiton World, v. 3, no. 4, December, p. 6-7.

Black Range Minerals Ltd., 2000, Annual report 2000: Sydney, Australia, Black Range Minerals Ltd., 37 p.

———2001, Quarterly report for the period ended 31 December 2000: Sydney, Australia, Black Range Minerals Ltd., 11 p.

Broken Hill Proprietary Co. Ltd., 2000, BHP announce discussions on Gag Island nickel project: Melbourne, Australia, Broken Hill Proprietary Co. Ltd. press release, July 12, 2 p.

Burstow, Clive, 2000, Cobalt—The changing emphasis—Supply, demand and price outlook for the cobalt market, *in* The Cobalt Conference, Tokyo, Japan, May 24-25, 2000, Proceedings: Guildford, United Kingdom, Cobalt Development Institute, 10 p.

Canmine Resources Corp., 2000, Canmine secures cobalt-silver feed to put refinery start well ahead of schedule: London, Ontario, Canada, Canmine Resources Corp. news release, January 20, 2 p.

———2001, Canmine in 2001: London, Ontario, Canada, Canmine Resources Corp. news release, April 5, 2 p.

Centaur Mining & Exploration Ltd., 2000, Report for the quarter ended 30 September 2000: South Melbourne, Australia, Centaur Mining & Exploration Ltd., 8 p.

———2001, Report for the quarter ended 31 December 2000: South Melbourne, Australia, Centaur Mining & Exploration Ltd., 10 p.

Cie. de Tifnout Tiranimine, 2001, CMBA—A global reference for high grade cobalt cathodes: Casablanca, Cie. de Tifnout Tiranimine brochure, 8 p.

Cobalt Development Institute, 2000, 6 monthly production statistics: Cobalt News, no. 4, October, p. 3-4.

———2001a, Cobalt in India: Cobalt News, no. 2, April, p. 9-11.

———2001b, Statistics review 2000: Cobalt News, no. 2, April, p. 12-14.

Comet Resources Ltd., 2001, December 2000 quarterly report: Perth, Western Australia, Comet Resources Ltd., 5 p.

Crew Development Corp., 2000a, Chibuluma South to be the first new mine in Zambia in 30 years, producing 18,000 tonnes per annum of copper: Vancouver, Canada, Crew Development Corp. news release, March 31, 1 p.

———2000b, Crew Development Corporation commences bankable feasibility study on the Mindoro nickel project: Vancouver, Canada, Crew Development Corp. news release, June 21, 2 p.

Cundy, Christopher, 2001, Cobalt heads for oversupply?: Metal Bulletin Monthly, no. 366, June, p. 51-52.

Defense National Stockpile Center, 2000, Annual Materials Plan for FY 2001—Amended to include columbium ferro: Fort Belvoir, VA, Defense National Stockpile Center news release, October 3, 2 p.

East Asia Gold Corp., 2000, Report and financial statements—March 31, 2000 and 1999: Toronto, East Asia Gold Corp., p. 11-12.

Falconbridge Ltd., 2001a, Annual report 2000: Toronto, Falconbridge Ltd., 57 p.

———2001b, 2000 annual information form: Toronto, Falconbridge Ltd., March 16, 52 p.

First Quantum Minerals Ltd., 2000, First Quantum/Glencore consortium complete transaction with ZCCM: Vancouver, Canada, First Quantum Minerals Ltd. news release, April 3, 2 p.

——— 2001, Annual information form for the year ended November 30, 2000 with updated information up to April 6, 2001: Vancouver, Canada, First Quantum Minerals Ltd., 42 p.

Formation Capital Corp., 2001a, Formation signs agreement to purchase refinery: Vancouver, Canada, Formation Capital Corp. press release, June 26, 1 p.

——— 2001b, Third quarter report to shareholders: Vancouver, Canada, Formation Capital Corp. press release, January 29, 1 p.

——— 2001c, 2001 annual report: Vancouver, Canada, Formation Capital Corp., 36 p.

Gellens, Luc, 2000, Cobalt in rechargeable batteries—A raw material supplier's view, *in* The Cobalt Conference, Tokyo, Japan, May 24-25, 2000, Proceedings: Guildford, United Kingdom, Cobalt Development Institute, 10 p.

Highlands Pacific Ltd., 2000, Activities report for the quarter ended 30 September 2000: Brisbane, Queensland, Australia, Highlands Pacific Ltd., 12 p.

Impala Platinum Holdings Ltd., 2000, Implats signs memorandum of understanding to gain 25% state in Philippines nickel project: Marshalltown, South Africa, Impala Platinum Holdings Ltd. press release, February 23, 1 p.

Inco Ltd., 2000, Inco to proceed with next phase of Goro nickel project—Pilot plant program proving successful: Noumea, New Caledonia, Inco Ltd. news

Digitized by Google

release, December 13, 2 p.
———2001, 2000 Annual report: Toronto, Inco Ltd., 78 p.
Interfax Mining & Metals Report, 2000a, Ufaleinikel commissions cobalt granulating furnace: Interfax Mining & Metals Report, v. 9, issue 39 (444), September 22-28, p. 13.
———2000b, Yuzhuralnikel may swap capacity for gas debts: Interfax Mining & Metals Report, v. 9, issue 18 (423), April 28-May 4, p. 11.
———2000c, Yuzhuralnikel shareholders vote for asset-debt swap: Interfax Mining & Metals Report, v. 9, issue 27 (432), June 30-July 6, p. 11.
———2000d, Yuzhuralnikel to raise nickel output, toll cobalt concentrate for Zaire: Interfax Mining & Metals Report, v. 9, issue 49 (454), December 1-7, p. 12-13.
———2001, Russia nonferrous metal production in 2000: Interfax Mining & Metals Report, v. 10, issue 6 (462), February 2-8, p. 30.
International Curator Resources Ltd., 2001, International Curator to relinquish Boleo and pursue new opportunities: Vancouver, Canada, International Curator Resources Ltd. news release, January 29, 1 p.
International Panorama Resource Corp., 2001, Quarterly report—December 31, 2000: Vancouver, Canada, International Panorama Resource Corp., 3 p.
M'Hamdi, Jamal-Iddine, 1996, The future of cobalt in Morocco, *in* Cobalt Industry Restructuring, New York, September 9-11, 1996, Proceedings: Gorham, ME, Gorham/Intertech Consulting, 11 p.
Masterman, Michael, 2000, Anaconda Nickel Limited, *in* 2000 Ryan's Notes Ferroalloys Conference, Boca Raton, FL, October 29-31, 2000, Proceedings: Pelham, NY, Ryan's Notes, 5 p.
Matheson, P.J., 1999, Actual and potential cobalt production in Australia and adjacent countries, *in* The Cobalt Conference, London, May 26-27, 1999, Proceedings: London, Cobalt Development Institute, 11 p.
Melkior Resources Inc., 2000a, Congo Copperbelt agreements recently completed: Montreal, Melkior Resources Inc. news release, February 15, 1 p.
———2000b, 2000 annual report: Montreal, Melkior Resources Inc., 12 p.
Metal Bulletin, 2000a, Moroccan Co output to increase in 2000: Metal Bulletin, no. 8492, July 13, p. 9.
———2000b, Mugabe 'accepts' end of Congo venture: Metal Bulletin, no. 8461, March 23, p. 8.
———2000c, OMG to target value-added nickel products: Metal Bulletin, no. 8508, September 14, p. 6.
———2000d, Opening up the cobalt market: Metal Bulletin, no. 8474, May 11, p. 19.
———2000e, Sumitomo Metal Mining looks at laterites in the Philippines: Metal Bulletin, no. 8470, April 27, p. 6.
———2000f, Tocantins expects to boost output, domestic sales: Metal Bulletin, no. 8440, January 10, p. 4.
———2000g, Ufaleynickel commissions new cobalt furnace: Metal Bulletin, no. 8512, September 28, p. 8.
———2001, Tocantins boosts nickel, cobalt capacity: Metal Bulletin, no. 8542, January 18, p. 4.
Ngcai, Z., 2001, Cobalt, *in* South Africa's Mineral Industry 1999/2000: Pretoria, South Africa, Mineral Economics Directorate, p. 68-72.
N.V. Union Minière S.A., 2001, Materials for a better life—Review of 2000 operations: Brussels, N.V. Union Minière S.A., 44 p.
OM Group Inc., 2000a, OM Group announces letter of agreement to jointly develop long term nickel feed source: Cleveland, OH, OM Group Inc. press release, February 25, 1 p.
———2000b, OM Group to expand vertical integration into nickel: Cleveland, OH, OM Group Inc. press release, February 23, 1 p.
———2001, 2000 annual report: Cleveland, OH, OM Group Inc., 20 p.
Outokumpu Oyj, 2000, Outokumpu to sell Harjavalta nickel plant to OM Group: Espoo, Finland, Outokumpu Oyj press release, February 23, 1 p.
Platt's Metals Week, 2000a, Orion at full cobalt output: Platt's Metals Week, v. 71, no. 25, June 19, p. 3.
———2000b, Philippine nickel ore output up: Platt's Metals Week, v. 71, no. 33, August 14, p. 7.
———2000c, Zambia works on new cobalt plant: Platt's Metals Week, v. 71, no. 5, January 31, p. 7.
Platts Metals Week, 2001a, Bulong Nickel hopes to survive, stabilize after rough start: Platts Metals Week, v. 72, no. 13, March 26, p. 7.
———2001b, Roan Antelope assets to be sold off: Platts Metals Week, v. 72, no. 12, March 19, p. 15.
PolyMet Mining Corp., 2000a, Polymet announces completion of fall core drilling program: Golden, CO, PolyMet Mining Corp. press release, December 18, 2 p.
———2000b, PolyMet's pilot plant results exceed expectations: Golden, CO, PolyMet Mining Corp. press release, August 22, 3 p.
Preston Resources Ltd., 2000a, Bulong Operations Pty Ltd. report for the month of December 1999: Perth, Australia, Preston Resources Ltd. media release, January 27, 5 p.
———2000b, Quarterly report for the period ending June 2000: Perth, Australia, Preston Resources Ltd. media release, 4 p.
———2001, Quarterly report for the period ending December 2000: Perth, Australia, Preston Resources Ltd., 4 p.
RAO Norilsk Nickel, 2000, Norilsk Nickel to develop its mieneral (sic) resources on the Kola peninsula: Moscow, RAO Norilsk Nickel press release, 1 p.
———2001, 2000 annual report: Moscow, RAO Norilsk Nickel, 50 p.
Reuters Ltd., 2000a, Anaconda's expansion plans move forward—CFO: New York, Reuters Ltd. press release, November 16, 2 p.
———2000b, Falconbridge plans partial December cobalt sales: London, Reuters Ltd. press release, November 13, 1 p.
———2000c, Japanese eye nickel project: Tokyo, Reuters Ltd. press release, April 20, 1 p.
———2000d, Update 1—Zambian bank puts Roan Antelope under receivership: Lusaka, Zambia, Reuters Ltd. press release, November 22, 1 p.
Roskill Information Services Ltd., 1995, Cobalt in the CIS: London, Roskill Information Services Ltd., 32 p.
Ryan's Notes, 2000, DLA awards Co at $13.77-14.276 per lb—Spot market steady on little business: Ryan's Notes, v. 6, no. 18, May 1, p. 1.
Searle, Peter, 2001, Strategic issues for the cobalt industry, *in* The Cobalt Conference, Toronto, Canada, May 16-17, 2001, Proceedings: Guildford, United Kingdom, Cobalt Development Institute, 10 p.
Sherritt International Corp., 2001, Consolidated financial statements and management's discussion and analysis: Toronto, Sherritt International Corp., 26 p.
Song, George, 2001, Chinese cobalt production & demand, *in* The Cobalt Conference, Toronto, Canada, May 16-17, 2001, Proceedings: Guildford, United Kingdom, Cobalt Development Institute, 23 p.
Southwood, Malcolm, and Gray, Paul, 2001, Cobalt, in Commodities focus, quarterly review, July 2001: London, J.B. Were & Son Ltd., p. 78-80.
Stillwater Mining Co., 2001, Form 10-K—Fiscal year ended December 31, 2000: Securities and Exchange Commission, 69 p.
Tenke Mining Corp., 2001, Report to shareholders—For the year ended December 31, 2000: Vancouver, Canada, Tenke Mining Corp., 21 p.
Terada, Ryoichi, 2000, Cobalt market in Japan—Who are the winners here in the past 10 years?, *in* The Cobalt Conference, Tokyo, Japan, May 24-25, 2000, Proceedings: Guildford, United Kingdom, Cobalt Development Institute, 16 p.
Titan Resources NL, 2000, Progress report—BioHeap development: West Perth, Western Australia, Titan Resources NL press release, August 24, 1 p.
U.S. Cobalt Inc., 2001, Interim financial statements to December 31, 2000: Denver, CO, U.S. Cobalt Inc., 13 p.
U.S. Department of Defense, 2001, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 1999 through September 2000: U.S. Department of Defense, p. 47.
Weda Bay Minerals Inc., 2000, Weda Bay Minerals commences feasibility study: Vancouver, Canada, Weda Bay Minerals Inc. press release, June 8, 2 p.
WMC Ltd., 1999, WMC markets cobalt on the internet: Melbourne, Australia, WMC Ltd. press release, August 16, 1 p.
Zambia Copper Investments Ltd., 2001, ZCI—Results: Hamilton, Bermuda, Zambia Copper Investments Ltd. press release, May 3, 2 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Cobalt. Ch. in Metal Prices in the United States Through 1998, 1999.
Cobalt. Ch. in Mineral Commodity Summaries, annual.
Cobalt. Ch. in Minerals Yearbook, annual.
Cobalt. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Cobalt. International Strategic Minerals Inventory Summary Report, Circular 930-F, 1987.
Cobalt. Mineral Industry Surveys, monthly.
Recycling—Metals. Ch. in Minerals Yearbook, annual.

Other

American Metal Market, daily.
Cobalt. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Cobalt Development Institute [United Kingdom].

Digitized by Google

Company annual reports and press releases.
Defense Logistics Agency, Defense National Stockpile Center.
Engineering & Mining Journal, monthly.
Federal Register, daily.
Interfax International Ltd., Mining & Metals Report, weekly.
Metal Bulletin [London], semiweekly and monthly.
Mining Journal [London], weekly, Metals & Minerals Annual Review, Mining Annual Review.
Platt's Metals Week, weekly.
Roskill Information Services Ltd. [London].
Ryan's Notes, weekly.
Strategic and Critical Materials Report to the Congress, U.S. Department of Defense.
The Materials Flow of Cobalt in the United States. U.S. Bureau of Mines Information Circular 9350, 1993.

TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons, cobalt content, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Consumption:					
Reported	7,990	8,910	9,130	8,410 r/	8,700
Apparent	9,380	11,200	11,500	10,700	11,700
Imports for consumption	6,710	8,430	7,670	8,150	8,770
Exports	1,660	1,570	1,680	1,550	2,630
Stocks, December 31:					
Industry 2/	794	763	751 r/	738 r/	780
U.S. Government 3/	18,700	17,100	14,700	13,200	10,200
Price, metal, per pound 4/	$25.50	$23.34	$21.43	$17.02	$15.16
World, production:					
Mine	26,200	27,200 r/	34,400 r/	30,600 r/	33,300 e/
Refinery	25,600	27,100 r/	30,900 r/	32,400 r/	35,200

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Stocks held by cobalt processors and consumers.
3/ Defense National Stockpile Center. Includes material committed for sale pending shipment.
4/ Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platt's Metals Week.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE SALES AND SHIPMENTS 1/

(Metric tons, cobalt content)

	1999	2000
Sales:		
Fiscal year 2/	1,960	2,720
Calendar year	2,230	3,080
Shipments: 3/		
Fiscal year 2/	1,670	2,150
Calendar year	1,530	2,960

1/ Data are rounded to no more than three significant digits.
2/ Twelve-month period ending September 30 of year stated.
3/ Calculated from year end inventory levels.

Source: Defense National Stockpile Center.

TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT 1/ 2/

(Metric tons, cobalt content)

	1999	2000
Consumption by end use:		
Steels	154	163 3/
Superalloys	3,830	3,800 3/
Alloys (excludes steels and superalloys):		
Magnetic alloys	794	544 3/
Other alloys 4/	291	1,020 3/
Cemented carbides 5/	755	760

See footnotes at end of table.

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TABLE 3--Continued
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT 1/ 2/

(Metric tons, cobalt content)

	1999	2000
Consumption by end use--Continued:		
Chemical and ceramic uses	2,530	2,360
Miscellaneous and unspecified	63 r/	63
Total	8,410 r/	8,700
Consumption by form:		
Chemical compounds (organic and inorganic) 6/	1,910	1,840
Metal	3,780	4,320
Purchased scrap	2,720	2,550
Total	8,410 r/	8,700
Stocks, December 31: 7/		
Chemical compounds (organic and inorganic) 6/	251	252
Metal	322	370
Purchased scrap	165	159
Total	738 r/	780

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes estimates.
3/ Data not comparable with those for 1999 because of a change in reporting.
4/ Includes nonferrous alloys, welding materials, and wear-resistant alloys.
5/ Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.
6/ Includes oxides.
7/ Stocks held by cobalt processors and consumers.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM 1/

(Metric tons unless otherwise specified)

		1999	2000
Metal: 2/			
Gross weight		6,800	7,210
Cobalt content 3/		6,800	7,210
Value	thousands	$229,000	$213,000
Oxides and hydroxides:			
Gross weight		1,260	1,540
Cobalt content 3/		910	1,110
Value	thousands	$33,700	$37,100
Other forms:			
Acetates:			
Gross weight		158	183
Cobalt content 3/		38	44
Value	thousands	$1,270	$1,290
Carbonates:			
Gross weight		58	5
Cobalt content 3/		27	2
Value	thousands	$548	$103
Chlorides:			
Gross weight		35	33
Cobalt content 3/		9	8
Value	thousands	$702	$295
Sulfates:			
Gross weight		1,360	1,490
Cobalt content 3/		366	402
Value	thousands	$9,840	$9,340
Total:			
Gross weight		9,670	10,500
Cobalt content 3/		8,150	8,770
Value	thousands	$275,000	$261,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys and waste and scrap.
3/ Estimated from gross weights.

Source: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY 1/

Country of origin	Metal 2/			Oxides and hydroxides			Other forms 3/			Total		
	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)
1999:												
Belgium	144	144	$6,720	264	190	$7,620	--	--	--	408	334	$14,300
Brazil	188	188	5,300	--	--	--	--	--	--	188	188	5,300
Canada	801	801	25,200	(5/)	(5/)	5	15	7	$303	815	807	25,500
China	--	--	--	30	22	687	6	2	82	36	24	769
Congo (Kinshasa)	1,090	1,090	37,700	--	--	--	--	--	--	1,090	1,090	37,700
Finland	1,130	1,130	37,600	609	438	15,300	1,490	397	10,900	3,230	1,970	63,800
France	45	45	3,490	54	39	2,620	2	1	21	101	85	6,130
Germany	86	86	3,320	78	56	2,500	18	5	131	182	147	5,950
Japan	57	57	3,140	1	(5/)	43	(5/)	(5/)	6	58	57	3,190
Netherlands	--	--	--	--	--	--	32	8	646	32	8	646
Norway	1,550	1,550	48,800	--	--	--	--	--	--	1,550	1,550	48,800
Russia	733	733	22,900	--	--	--	(5/)	(5/)	4	733	733	22,900
South Africa	7	7	370	--	--	--	2	(5/)	14	8	7	384
United Kingdom	85	85	3,030	228	164	4,900	46	20	239	359	269	8,180
Zambia	879	879	31,100	--	--	--	--	--	--	879	879	31,100
Other	(5/)	(5/)	37	(5/)	(5/)	12	--	--	--	1	1	49
Total	6,800	6,800	229,000	1,260	910	33,700	1,610	440	12,400	9,670	8,150	275,000
2000:												
Australia	288	288	7,370	2	1	53	(5/)	(5/)	3	290	290	7,430
Belgium	118	118	4,820	411	296	11,300	2	1	25	531	415	16,100
Brazil	340	340	9,380	--	--	--	--	--	--	340	340	9,380
Canada	809	809	24,900	1	1	57	4	2	70	815	812	25,000
China	12	12	474	15	11	363	4	1	34	31	24	871
Congo (Kinshasa)	893	893	22,200	--	--	--	--	--	--	893	893	22,200
Finland	1,290	1,290	41,400	900	648	19,400	1,630	436	10,300	3,820	2,380	71,100
France	43	43	3,250	42	30	2,000	--	--	--	85	73	5,250
Germany	75	75	3,040	5	4	100	(5/)	(5/)	14	80	79	3,150
Japan	82	82	3,850	2	2	44	(5/)	(5/)	8	85	84	3,910
Morocco	62	62	1,570	--	--	--	--	--	--	62	62	1,570
Netherlands	10	10	284	--	--	--	--	--	--	10	10	284
Norway	1,470	1,470	42,900	--	--	--	--	--	--	1,470	1,470	42,900
Russia	1,100	1,100	32,100	--	--	--	11	3	100	1,110	1,100	32,200
South Africa	243	243	5,730	21	15	468	--	--	--	264	258	6,200
Uganda	41	41	1,220	--	--	--	--	--	--	41	41	1,220
United Kingdom	10	10	311	136	98	3,320	52	12	399	198	120	4,030
Zambia	318	318	7,510	--	--	--	--	--	--	318	318	7,510
Other	11	11	329	--	--	--	6	2	63	17	12	392
Total	7,210	7,210	213,000	1,540	1,110	37,100	1,710	457	11,000	10,500	8,770	261,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys and waste and scrap.
3/ Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.
4/ Estimated from gross weights.
5/ Less than 1/2 unit.

Source: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

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TABLE 6
U.S. EXPORTS OF COBALT IN 2000, BY COUNTRY 1/ 2/

Country of destination	Metal 3/		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Gross weight (metric tons)	Value 4/ (thousands)	Cobalt content 5/ (metric tons)	Value 4/ (thousands)
Austria	20	$164	(6/)	$7	--	--	--	--	20	$170
Belgium	602	23,800	15	131	--	--	2	$39	613	24,000
Brazil	8	166	54	968	70	$657	--	--	64	1,790
Canada	106	3,020	42	999	36	273	43	449	156	4,750
France	180	4,330	3	16	--	--	--	--	183	4,350
Germany	81	3,520	--	--	--	--	--	--	81	3,520
Hong Kong	55	2,150	11	427	--	--	--	--	63	2,580
Japan	124	4,900	24	277	1	15	--	--	141	5,190
Korea, Republic of	8	370	881	3,840	--	--	--	--	642	4,210
Mexico	27	1,150	16	519	233	1,470	--	--	94	3,140
Netherlands	199	5,710	139	2,320	--	--	--	--	299	8,030
Singapore	2	107	23	132	--	--	--	--	19	239
Switzerland	16	535	--	--	--	--	--	--	16	535
Taiwan	16	275	14	436	12	105	3	38	30	854
United Kingdom	39	2,440	(6/)	3	234	367	(6/)	6	95	2,820
Other	42	1,850	94	1,650	36	167	5	69	120	3,730
Total	1,520	54,500	1,320	11,700	623	3,050	53	601	2,630	69,900

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.
3/ Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.
4/ Free alongside ship (f.a.s.) value.
5/ Estimated from gross weights.
6/ Less than 1/2 unit.

Source: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY, DECEMBER 31, 2000 1/ 2/

(Metric tons, cobalt content)

Country	Capacity
Australia e/	3,500
Belgium	1,200
Brazil	800
Canada	5,100
China e/	1,900
Congo (Kinshasa)	17,000
Finland	10,000
France	300
India	370
Japan	480
Morocco	1,200
Norway	4,500
Russia e/	8,000
South Africa e/	1,000
Uganda e/	500
Zambia	5,000
Total	60,900

e/ Estimated.
1/ Data are rounded to no more than three significant digits; may not add to total shown
2/ Refinery products include cobalt metal, metal powder, oxides, and/or salts.

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TABLE 8
COBALT: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1996	1997	1998	1999	2000 e/
Australia e/ 4/	2,800	3,000	3,300	4,100 r/	5,600
Botswana 5/	408	334	335	331 r/	319 6/
Brazil e/	400	400	400	700	900
Canada 7/	5,714	5,709	5,861	5,323 r/	5,281 6/
China e/	190	200	40	250 r/	200
Congo (Kinshasa) e/ 8/	2,000	3,500	5,000 r/	6,000 r/	7,000
Cuba 9/	2,011	2,082	2,200	2,160	2,350
Kazakhstan e/ 10/	300	300	300	300	300
Morocco 11/	565	714	287	863 r/	1,305 6/
New Caledonia e/ 12/	1,100	1,000	1,000	1,100	1,100
Russia e/	3,300	3,300	3,200	3,300	3,600
South Africa e/	350	465 r/	435 r/	450 r/	585
Zambia 11/ 13/	6,959	6,037	11,900	5,640 r/	4,600
Zimbabwe e/ 14/	106	126	138 r/	121 r/	126 6/
Total	26,200	27,200 r/	34,400 r/	30,600 r/	33,300

e/ Estimated. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 2001. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from copper, nickel, platinum, or zinc operations. Morocco was the only country where cobalt was mined as a primary product.

3/ In addition to the countries listed, Bulgaria, Indonesia, the Philippines, and Poland are known to produce ores that contain cobalt, but information is inadequate for reliable estimates of output levels. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

4/ Quantities of cobalt contained in intermediate or refined metallurgical products produced from Australian and imported ores. Cobalt content o latertic nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, metric tons: 1996--1,400; 1997--1,600; 1998--4,000; 1999--7,000; and 2000--5,100.

5/ Reported cobalt content of pelletized nickel-copper matte.

6/ Reported figure.

7/ Assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper matte shipped to Norway for refining, was reported as follows, in metric tons: 1996--2,150; 1997--2,168; 1998--2,262; 1999--2,014 (revised); and 2000--2,013.

8/ Cobalt content of concentrates and tailings.

9/ Determined from reported nickel-cobalt content of sulfide production.

10/ Estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be as follows, in metric tons: 1996-2000--1,400.

11/ Cobalt content of concentrates.

12/ Quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride, cobalt oxide hydroxide, and cobalt sulfide) produced from New Caledonian ores exported to Australia and France. Cobalt content of total ores mined is estimated as follows, in metric tons: 1996--12,200; 1997--13,600; 1998--12,500 (revised); 1999--11,000 (revised); and 2000--12,000.

13/ Data for 1996 through 1998 are for the fiscal years beginning April 1; data for 1999 through 2000 are for the calendar years.

14/ Cobalt content of intermediate products produced in Zimbabwe from ores originating in Botswana and Zimbabwe.

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TABLE 9
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1996	1997	1998	1999	2000
Australia: Metal (including metal powder) and oxide hydroxide	--	617	1,395	1,700 e/	2,600 e/
Belgium: Metal powder, oxide, hydroxide e/	1,200	1,200	1,200	950	1,110
Brazil: Metal	193	266	364	651 r/	792
Canada: Metal (including metal powder) and oxide	3,601	3,792	4,415	4,196 r/	4,376
China: Metal e/	230	470	410	300 r/	350
Congo (Kinshasa): Metal 4/	3,540	2,808	4,490	5,180 r/	4,320
Finland: Metal powder and salts	4,160	5,000	5,250	6,200	7,700
France: Chloride	174	159	172	181	204
India: Metal and salts e/	--	110	120	120	206
Japan: Metal	258	264	329	247 r/	311
Morocco: Metal	80	225 r/	242 r/	472 r/	1,200
Norway: Metal	3,098	3,417	3,851	4,009	3,433
Russia: Unspecified e/	4,200	4,100	3,500	3,600	4,400
South Africa: Metal powder and sulfate	244	316 r/	296	306	397
Uganda: Metal	--	--	--	77	420
Zambia: Metal 5/	4,612	4,403	4,837	4,236 r/	3,342
Total	25,600	27,100 r/	30,900 r/	32,400 r/	35,200

e/ Estimated. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 2001. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

3/ In addition to the countries listed, Germany and Slovakia may produce cobalt, but available information is inadequate to make reliable estimates of production.

4/ Excludes production of cobalt in white alloy, matte, and slag that would require further refining.

5/ Data for 1996 through 1998 are for the fiscal years beginning April 1; data for 1999 through 2000 are for the calendar years.

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COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Columbium [Niobium (Nb)] is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but, in most cases, they are less desirable.

Tantalum (Ta) is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications. Neither columbium nor tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex, and most are not currently (2000) recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean Conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of total estimated columbium mine production in 2000. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore.

Columbium (Niobium) and Tantalum in the 20th Century

Columbium.—Columbium (niobium) was discovered in 1801; prior to 1918, however, most U.S. interest in columbium was for experimental purposes. Commercial columbium usage began around 1925 when it was added to tool steel as a substitute for tungsten. In 1933, columbium (in the form of ferrocolumbium) was first used in stainless steel, and about 1935, columbium was added to superalloys for use in gas turbines. About 3.5 metric tons of columbium-bearing minerals valued at about $4,520 was reported shipped from domestic mines in 1935. Imports of columbium-bearing minerals were about 540 tons valued at about $107,000, with Nigeria accounting for most of the imports. Nigeria was the leading source for columbium-bearing minerals, and the country shipped its entire output to the United States.

In 2000, there was no domestic columbium mining, and the United States satisfied its columbium requirements primarily by importing ferrocolumbium and columbium oxide from Brazil, ferrocolumbium from Canada, and columbium-bearing mineral concentrates for processing mainly from Australia and Nigeria. U.S. columbium imports totaled about 6,500 tons of contained columbium valued at about $110 million. Brazil and Canada were the world's largest producers of columbium minerals, together accounting for more than 95% of the total. Ferrocolumbium and columbium metal, alloys, and compounds were produced in the United States by six companies located mostly in the eastern United States. Columbium consumption in the United States was mainly as ferrocolumbium by the steel industry and as high-purity columbium alloys and metal by the aerospace industry. Steelmaking accounted for more than 75% of reported columbium consumption, with the value of consumption estimated to be about $70 million.

Tantalum.—Tantalum was discovered in 1802. Commercial use of tantalum began in Germany in 1903 with the production of tantalum wire to replace carbon in incandescent light filaments. By 1909, tungsten began to replace tantalum in filaments, and by 1912, the substitution was complete. During this period, U.S. tantalum requirements were imported from Germany. By 1918, U.S. demand for tantalum for experimental purposes was large enough that about 2 metric tons of tantalum-bearing minerals valued at about $2,250 was marketed from material mined in South Dakota. Tantalum carbide was produced in the United States in 1929, and the tantalum capacitor was developed in 1940. There was no reported domestic tantalum mine production in 1940, and U.S. imports of tantalum minerals totaled about 222 tons valued at about $260,000. Australia was thought to be the major producer of tantalum minerals at that time.

In 2000, there was no domestic tantalum mining, and the United States satisfied its tantalum requirements by importing alloys, metal, and powder from China, Japan, and Thailand, and tantalum-bearing mineral concentrates for processing mainly from Australia, Canada, and Nigeria. U.S. tantalum imports totaled more than 900 tons of contained tantalum valued at more than $190 million. Australia was the world's largest producer of tantalum mineral concentrates and accounted for more than 60% of U.S. imports. Tantalum metal, alloys, and powders were produced in the United States by three companies located in the eastern part of the United States. The major use (more than 60%) for tantalum as tantalum metal powder was in the production of electronic components, mainly tantalum capacitors. Tantalum was also consumed in cemented carbides and in superalloys. The value of tantalum consumed in the United States in 2000 was estimated to be about $200 million.

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Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came from the mining of columbite in Nigeria and tantalite-columbite, mostly in Australia, Brazil, and certain African countries. Tantalum mineral was produced mostly from tantalite-columbite mining operations in Australia, which was almost 60% of total estimated tantalum mine production in 2000, and from other tantalum mine operations in Brazil, Burundi, Canada, Congo (Kinshasa), Ethiopia, Nigeria, and Rwanda. The reliance on tantalum-containing tin slags as a source of tantalum supply remained low.

The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia, the major source for tantalum. The Defense National Stockpile Center (DNSC) offered and sold selected columbium and tantalum materials from the National Defense Stockpile (NDS). The Generalized System of Preferences (GSP), a renewable preferential trade program, was extended to September 30, 2001. Columbium price quotations remained stable. Tantalum price quotations for tantalite ore escalated amidst concerns about the status of the world tantalum supply. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased, with demand for columbium in superalloys up significantly. Tantalum consumption increased.

Legislation and Government Programs

Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively. To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the NDS. The Stockpile goals, effective as of October 5, 1999, for tantalum metal powder and tantalum metal (contained tantalum) were about 16 metric tons (t) and about 55 t, respectively (table 3). The NDS had no goals for columbium materials. For fiscal year (FY) 2000 (October 1, 1999, through September 30, 2000), the DNSC sold about 182 t of columbium contained in ferrocolumbium valued at about $2.8 million, and about 9 t of columbium contained in columbium metal ingots valued at about $567,000 and disposed of about 80 t of columbium contained in tantalum minerals that were sold in FY 2000; no columbium value was obtained, as the columbium was contained within the tantalum minerals. Additionally, the DNSC sold about 2 t of tantalum contained in tantalum carbide powder valued at about $254,000, about 23 t of tantalum contained in tantalum metal powder valued at about $3.67 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $3.84 million, about 134 t of tantalum contained in tantalum minerals valued at about $42.7 million, and about 9 t of tantalum contained in tantalum oxide valued at about $1.32 million. As of September 30, 2000, columbium and tantalum inventory sold but not shipped from the NDS included about 37 t of columbium contained in ferrocolumbium and about 106 t of tantalum contained in tantalum minerals (U.S. Department of Defense, 2001, p. 14, 15, 43, 45, 47, 48).

In its revised Annual Materials Plan (AMP) for FY 2001 (October 1, 2000, through September 30, 2001) and proposed AMP for FY 2002 (October 1, 2001, through September 30, 2002), the DNSC had authority to sell about 10 t of columbium contained in columbium carbide powder (actual quantity limited to the remaining sales authority or inventory), about 254 t of columbium contained in columbium concentrates, about 68 t of columbium contained in ferrocolumbium (actual quantity limited to the remaining sales authority or inventory), about 9 t of columbium contained in columbium metal ingots, about 2 t of tantalum contained in tantalum carbide powder, about 23 t of tantalum contained in tantalum metal powder (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 18 t of tantalum contained in tantalum metal ingots (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 227 t of tantalum contained in tantalum minerals, and about 9 t of tantalum contained in tantalum oxide (Defense National Stockpile Center, 2001a, b). For FY 2001, through June 30, 2001, the DNSC sold about 48 t of columbium contained in ferrocolumbium valued at about $1.29 million, about 9 t of columbium contained in columbium metal ingots valued at about $142,000, about 20 t of tantalum contained in tantalum capacitor-grade metal powder valued at about $14.3 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $16.1 million, about 2 t of tantalum contained in tantalum carbide powder valued at about $1.34 million, and about 11 t of tantalum oxide valued at about $2.55 million.

Under the GSP, the United States grants duty-free access to eligible products from designated developing countries. In 2000, U.S. import duties for selected columbium and tantalum materials ranged from duty free to 8.5% ad valorem for normal-trade-relations (NTR) status and from duty free to 45% ad valorem for non-NTR status (U.S. International Trade Commission, 1999). In March, the GSP program, which expired on June 30, 1999, was renewed through September 30, 2001, retroactive to July 1, 1999, by a provision in the Ticket To Work and Work Incentives Improvement Act of 1999. Customs began processing refunds due to the renewal on January 7, 2000 (U.S. Customs Service, 2000). Categories of U.S. imports from developing countries affected by the GSP included all columbium and tantalum tariff articles except columbium and tantalum ores and concentrates, synthetic tantalum-columbium concentrates, and columbium and tantalum unwrought waste and scrap, for which the general rate of duty already was zero.

Production

Neither columbium nor tantalum was mined domestically in 2000. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2000 were, however, incomplete at the time this report was prepared.

Cabot Performance Materials, Boyertown, PA, had production capability that ranged from raw material processing through the production of columbium and tantalum end products. In September, Cabot proceeded with the company's decision to close its Revere, PA, plant, which had produced high-purity ferrocolumbium and nickel columbium. Shieldalloy Metallurgical Corp., Newfield, NJ, was a producer of ferrocolumbium. H.C. Starck Inc. was a major supplier of tantalum and columbium products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and

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tantalum carbides (table 9).

In July, KEMET Corp., Greenville, SC, announced planned expansion of more than 7,900 square meters (m^2) of manufacturing floor space in South Carolina and Mexico dedicated to the production of solid tantalum and conductive polymer tantalum capacitors. With increasing customer demand for capacitors, KEMET, a major world maufacturer of tantalum capacitors, indicated that the capacity expansions would ensure the company's ability to provide high-value tantalum and high-frequency organic tantalum capacitors to meet its customers' needs. About 1,000 m^2 of manufacturing space would be created with additions in Mauldin and Greenwood, SC; relocation of support functions in Simpsonville, SC, would add 418 m^2; and construction of a new facility in Matamoros, Mexico, would add 6,500 m^2. The new capacity at each facility would be used to increase production rates for solid tantalum surface-mount capacitors. New capacity in Mauldin and Simpsonville would also increase production rates for KEMET's new high-performance conductive polymer tantalum capacitor. The expansions were expected to add approximately 1,100 new jobs (KEMET Corp., 2000b).

In November, KEMET announced a memorandum of understanding with Australasian Gold Mines NL (AGM) to establish a 50-50 joint venture, which would own and fund development of AGM's existing tantalum projects, including a pilot-processing plant at Dalgaranga, Australia. The feasibility of future mining and commissioning of full-scale plants would be determined. KEMET would purchase processed tantalum products from the pilot plant and any future processing development. The material would be toll converted into tantalum powder necessary for the production of capacitors. In February 2001, KEMET announced completion of the joint-venture agreement with AGM. KEMET's initial investment in the venture would be approximately $5.5 million, and KEMET would acquire a 10% interest in AGM for approximately $2.5 million. When full-scale mining operation is achieved, KEMET anticipates that the venture could ultimately provide up to 10% to 15% of its total annual tantalum requirements (KEMET Corp., 2000a; 2001).

Consumption

Overall U.S. reported consumption of columbium as ferrocolumbium and nickel columbium rose by almost 20% compared with that of 1999 (table 4). Consumption of columbium by the steelmaking industry increased by more than 10% as a result of an increase in raw steel production, with consumption up in all major reported steel end-use categories. Demand for columbium in superalloys increased significantly to more than 940 t, reflecting strong demand from the aerospace industry. That portion used in the form of nickel columbium increased to about 600 t. Overall U.S. apparent consumption of all columbium materials was estimated to be about 4,300 t, compared with about 4,100 t in 1999.

Estimated overall U.S. apparent consumption of all tantalum materials increased by more than 15% to about 650 t, owing to continued strong demand for tantalum powder for the production of tantalum capacitors. More than 60% of total tantalum consumed was in the electronics industry. Major end uses for tantalum capacitors included portable telephones, pagers, personal computers, and automotive electronics. Tantalum consumption was also affected by increased demand for tantalum-containing superalloys for jet engine and gas turbine components.

Columbium.—"Columbium" and "niobium" are synonymous names for the chemical element with atomic number 41; "columbium" was the name given in 1801, and "niobium" was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity well and is characterized by a high melting point (about 2,470 °C), resistance to corrosion, and ease of fabrication.

Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in nickel-, cobalt-, and iron-base superalloys for such applications as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten carbide-based material. It is usually used with carbides of such metals as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of high-purity ferrocolumbium, nickel columbium, columbium metal, and columbium carbide. Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include computers, communication systems, and instruments and controls for aircraft, missiles, ships, and weapon systems. Because of its high melting point (about 3,000° C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in cemented-carbide cutting tools, wear-resistant parts, farm tools, and turning and boring tools. Because of tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used in the chemical industry in such applications as heat exchangers, evaporators, condensers, pumps, and liners for reactors and tanks. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually used at either a performance or economic penalty.

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates were consumed internally by producers of regular-grade ferrocolumbium and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The columbium price is affected most by the availability of regular-grade ferrocolumbium produced from pyrochlore. The American Metal Market published price for regular-grade ferrocolumbium ranged from

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$6.75 to $7 per pound of contained columbium and has not changed since September 1997.

The Metal Bulletin price for columbite ore, which is based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), quoted since February 1995 at a range of $2.80 to $3.20 per pound, rose to a range of $5.50 to $7 in late November, where it remained through December. The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium ranged from $17.50 to $18 per pound of contained columbium and has not changed since September 1997. Industry sources indicated in December 1999 that nickel columbium sold at about $18.50 per pound of contained columbium, columbium metal products sold in the range of about $24 to $100 per pound in ingot and special shape forms, and columbium oxide for master alloy production sold for about $8.80 per pound (Mining Journal, 1999a; Tantalum-Niobium International Study Center, 1999a, p. 5). Significant events affecting columbium prices since 1958 include the following: 1960-70, development of pyrochlore deposits in Brazil and Canada; 1970-79, increased demand and rising prices; 1980, columbium oxide produced from pyrochlore-based feed material; 1981, exports of Brazilian pyrochlore ceased; 1994, production of ferrocolumbium began in Canada; 1997-98, sales of ferrocolumbium from the NDS; and 1998, expansion of ferrocolumbium production capacity in Brazil (Cunningham, 1999a).

The price for tantalum products is affected most by events in the supply of and demand for tantalum minerals. During 2000, published prices for tantalite ore (per pound contained oxide) rose significantly: Platt's Metals Week, rose to a range of $145 to $175 from a range of $33 to $35; Metal Bulletin, rose to a range of $180 to $240 from a range of $28 to $31.50; and Ryan's Notes, rose to a range of $250 to $300 from a range of $45 to $48. Strong global demand and an apparent shortage of tantalum source materials for processing contributed to the price increase. In 2000, sales of tantalum minerals from the NDS averaged about $118 per pound contained tantalum oxide. In July 2001, published prices for tantalite ore (per pound contained oxide) were as follows: Platt's Metals Week, a range of $75 to $100; Metal Bulletin, a range of $55 to $75; Ryan's Notes, a range of $48 to $55. The decrease in price reportedly was due in part to excess tantalum inventories and a downturn in tantalum demand from the electronics sector. The Metal Bulletin published price for Greenbushes tantalite ore, Australia, was $40 per pound contained oxide and has not changed since April 1991. The most recent industry source (August 1999) on tantalum product prices indicated that the average selling prices per pound of contained tantalum for some tantalum products were as follows: capacitor-grade powder, $135 to $260; capacitor wire, $180 to $270; and vacuum-grade metal for superalloys, $75 to $100 (Mining Journal, 1999b). Presumably these prices increased in 2000, based on the escalating price for tantalum ore, but public information on prices for these products was not available. Significant events affecting tantalum prices since 1958 include the following: 1979-80, tantalum price accelerates to record levels; 1982, industry's accumulation of large tantalum material inventories; 1988, drawdown of tantalum material inventories by processors; 1990, purchase of tantalum materials for the NDS; 1991, long-term tantalum supply contracts between major producer and processors; and 1998, sales of tantalum minerals from the NDS (Cunningham, 1999b).

Foreign Trade

Table 5 lists columbium and tantalum export and import data. Net trade for columbium and tantalum continued at a deficit. Overall trade value for exports increased significantly with total volume down slightly. In descending order, Israel, the United Kingdom, Japan, Germany, and China were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 80% of the total. For imports, overall trade value was up by about 35%, with total volume up by more than 10%. In descending order, Brazil, Japan, Australia, China, Germany, and Canada were the major sources of columbium and tantalum imports, on the basis of value, with more than 70% of the total.

Imports for consumption of columbium ores and concentrates increased by about 60% (table 6); imports from China accounted for more than 20% of quantity and value. Imports at an average grade of approximately 30% Nb_2O_5 and 31% Ta_2O_5 were estimated to contain about 30 t of columbium and about 40 t of tantalum. Ferrocolumbium and columbium oxide imports were down slightly; Brazil accounted for more than 80% of U.S. ferrocolumbium imports and about 40% of columbium oxide imports.

Imports for consumption of tantalum ores and concentrates increased twofold (table 7); imports from Australia accounted for more than 60% of quantity and about 55% of value. Imports at an average grade of approximately 37% Ta_2O_5 and 18% Nb_2O_5 were estimated to contain about 610 t of tantalum and about 270 t of columbium.

The schedule of tariffs applied during 2000 to U.S. imports of selected columbium and tantalum materials is found in the Harmonized Tariff Schedule of the United States—2000 (U.S. International Trade Commission, 1999). Brazil, which was the major source for U.S. columbium imports, accounted for about 68% of total, in units of contained columbium (figure 1), and Australia, which was the major source for U.S. tantalum imports, accounted for about 48% of total, in units of contained tantalum (figure 2).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2000, net import reliance as a percent of apparent consumption was 100%. For tantalum, net import reliance as a percent of apparent consumption was estimated to be about 80%.

World Review

Industry Structure.—Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Congo (Kinshasa) were the major producers of tantalum mineral concentrates. The importance of tantalum-containing tin slags as a source of tantalum supply has decreased owing to structural changes in the tin industry. Tantalum-containing tin slags account for about 18% of tantalum supply compared with about 70% 20 years ago (Mining Journal, 2000b; Tantalum-Niobium International Study Center, 1998, p. 2-6).

Australia.—For its 1999-2000 financial year ending June 30,

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2000, Sons of Gwalia Ltd., West Perth, Western Australia, reported that tantalum production (tantalum oxide contained in mineral concentrates) totaled about 505 t at its Greenbushes and Wodgina Mines and that tantalum sales totaled about 500 t. Greenbushes production was about 315 t, and sales, about 314 t. Production at Wodgina was about 190 t, and sales, about 186 t. Existing "main production" at Greenbushes will be exhausted in 1993. Annual production capacity at Greenbushes is planned to be expanded from about 320 t to about 590 t. The existing processing facility will be expanded from about 1.6 million metric tons (Mt) of ore to more than 2.75 Mt. Preproduction capital cost for underground development at the mine, and capital cost for expansion of the existing processing facilities, total about $65 million. At Wodgina, annual production capacity will be increased over the next 2 years to more than 450 t, with plant processing capacity increasing to at least 2 Mt of ore. Capital cost for the Wodgina expansion will be approximately $35 million. By 2003, total company annual sales of contained tantalum oxide were expected to build to at least about 1,040 t. Forecast production increases from development of an underground operation at Greenbushes and the plant expansions at Greenbushes and Wodgina were expected within 3 years, with construction activities scheduled to commence in early 2001. Greenbushes existing production and the increased production from the Wodgina expansion were committed to Cabot Corp. and H.C. Starck of Germany under long-term contracts through to calender year 2005 (Sons of Gwalia Ltd., 2000, p. 7, 22-26).

In its quarterly report for March 31, 2001, Sons of Gwalia reported that Greenbushes tantalum "resource base" was about 44,000 t of contained tantalum oxide, including about 20,400 t classified as tantalum reserves. As a result of a successful drilling program, Wodgina's tantalum "resource base" doubled to about 27,200 t of contained tantalum oxide, including about 24,000 t classified as tantalum reserves (Sons of Gwalia Ltd., 2001, p. 9, 10).

Brazil.—Cia. Brasileira de Metalurgia e Mineração (CBMM), which was the world's largest columbium producer, completed its $80 million expansion program that was initiated in 1998. Annual columbium ore concentration capacity was increased to about 84,000 t of concentrate, and annual ferrocolumbium capacity increased to about 45,000 t. The new concentration plant uses a pyrometallurgical process, which replaced a leaching plant. In 2000, CBMM was expected to produce about 51,000 t of concentrate, about 30,000 t of ferrocolumbium, and about 2,000 t of columbium oxide for use in the aerospace industry. In 1999, CBMM reportedly produced about 40,000 t of concentrate and about 25,000 t of ferrocolumbium. For 2001, CBMM planned to increase concentrate output to about 55,000 t and to increase ferrocolumbium output to about 33,000 t. CBMM was said to export 95% of its ferrocolumbium production, mostly to Europe and North America, 35% each, and to Japan, 16% (American Metal Market, 2000; TEX Report, 2000).

Canada.—Production of columbium oxide contained in pyrochlore concentrate at the Niobec Mine near Chicoutimi, Quebec, was about 3,270 t compared with about 3,370 t in 1999. Niobec was a 50-50 joint venture between Cambior Inc. (product marketing), and Teck Corp. (operator). Columbium contained in ferrocolumbium production was about 2,170 t compared with about 2,290 t in 1999. Pyrochlore-to-ferrocolumbium converter recovery was 96.2% compared with 97.1% in 1999. Ore milled increased to 907,000 t as the mill operated, on the average, at about 2,480 metric tons per day. Average recovery decreased to 54.6%, with the Nb_2O_5 grade of concentrate at 66%. Operating cost, dollars per metric ton of ore milled, was about $37.30 compared with about $36.10 in 1999. Capital expenditures were $9 million, including $7 million for expansion of mill and converter capacities. For 2001, capital costs were forecast at $3 million, including $2 million for underground development and equipment. Teck reported proven and probable ore reserves of 11.5 Mt grading 0.51% columbium. In November, Teck reached an agreement to sell its 50% interest in Niobec to Mazarin Inc., Quebec, for $47 million. The transaction was expected to be closed in the first half of 2001, with Teck expecting to record a pretax gain of $25 million on the sale (Cambior Inc., 2001, p. 11; Teck Corp., 2001, p. 24, 32, 58). As part of its financial restructuring, Cambior entered into an agreement with Jipangu Inc., a Japanese investment company, and a financial institution for a mortgage loan on its 50% interest in Niobec for $13 million. The term was for 4.5 years repayable in 16 consecutive quarterly installments commencing on March 30, 2001, with a maturity date of December 31, 2004. The mortgage was secured by Cambior's 50% interest in Niobec and its share of the cash flow generated by the mine. On January 18, 2001, Jipangu agreed to a $6.3 million private placement to subscribe to 15 million common shares of Cambior at a price of $0.42 per share, with proceeds from the private placement used to repay in part Jipangu's mortgage loan (Cambior Inc., 2001, p. 24, 25, 37).

In 2000, about 69 t of tantalum oxide contained in concentrate was produced at the Bernic Lake, Manitoba, tantalum operation, compared with about 66 t in 1999.

In October, it was reported that Avalon Ventures Ltd., Toronto, had finalized a joint-venture agreement with Global Canada Co., a private Nova Scotia company controlled by BSAV Inc., a private Delaware company. Global would have the right to earn up to 75% interest in any of Avalon's Canadian tantalum exploration properties, Lilypad Lakes, Raleigh Lake, and East Braintree. Global would have the right to earn an initial 50% interest in any of the properties by providing $5 million in exploration and development funding before December 31, 2002, or upon delivery of a feasibility study. The interest in any one property could be increased to 75% by Global arranging financing to bring a tantalum mine into production. Initial commitment by Global was to provide $1 million to fund work programs on the properties and to provide working capital. The program had a budget of $750,000 to be spent by December 31, 2000. Avalon would be the operator of the exploration programs, and Global would have the right to participate in any other tantalum exploration properties acquired by Avalon in Canada. Lilypad Lakes near Pickle Lake, Ontario, had top priority with a program budget of $580,000. A preliminary diamond drilling program completed in April intersected tantalum mineralization occurrences averaging 0.05 % Ta_2O_5 across 11.5 meters (m), 0.036% Ta_2O_5 across 24 m, and 0.076% Ta_2O_5 across 7 m. In addition, a surface program involving mapping, sampling, lithogeochemistry, and a gravity survey discovered a new high-grade tantalum occurrence. Assays of 10 random samples indicated tantalum ranging from 0.131% to 0.422% Ta_2O_5. A minimum 1,100-m diamond drilling program was scheduled to begin on the property in November (Avalon Ventures Ltd., 2000a, b;

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Skillings Mining Review, 2000).

China.—China's Jiujiang Nonferrous Metals Smelter, eastern Jiangxi Province, completed an upgrade to its tantalum production line which increased annual production capacity to about 20 t from 2 t to 3 t. Existing production ceased in January and new production started in mid-August. However, owing to raw material shortages, output was expected to reach only about 4 t by January 2001. Jiujiang's annual columbium production capacity was about 20 t, with output in 2000 expected to be about 15 t. Annual production capacity for tantalum oxide and columbium oxide was about 100 t and 300 t, respectively, with tantalum oxide output in 2000 expected to be about 70 t and columbium oxide output about 100 t. In 1999, tantalum oxide output was about 60 t and columbium oxide output about 100 t (Platt's Metals Week, 2000).

Congo (Kinshasa).—In June, the President of the Security Council, United Nations, requested the Secretary-General to establish a panel of experts on the illegal exploitation of natural resources and other forms of wealth of the Democratic Republic of the Congo for a period of 6 months. The report of the panel was transmitted to the President on April 12, 2001. The panel's recommendations revolved around six broad themes: "(1) sanctions against countries and individuals involved in the illegal activities; (2) preventive measures to avoid a recurrence of the current situation; (3) reparations to the victims of the illegal exploitation of natural resources; (4) design of a framework for reconstruction; (5) improvement of international mechanisms and regulations governing some natural resources; and (6) security issues." Categories that were of primary consideration included coltan (columbium and tantalum). Some of the panel's recommendations for Security Council action included an immediate temporary embargo on the import or export of coltan and pyrochlore; the freezing of financial assets of the rebel movements and their leaders; the freezing of financial assets of the companies or individuals who continue to participate in the illegal exploitation of the natural resources of the Congo immediately after publication of the report; and the declaration of an immediate embargo on supply of weapons and all military material to rebel groups operating in Congo (United Nations, 2001).

Greenland.—Angus and Ross plc, a United Kingdom company with tantalum interest in Ireland, received a licence from the Greenland Government for rights to explore for tantalum in southern Greenland centered in an area 20 kilometers east of the southern capitol of Narsarsuaq. The area of interest is the Motzfeld Centre, an alkaline igneous ring complex, with pyrochlore the most important economic mineral phase. Data suggest that resources could be about 50 Mt of ore grading in the range of 0.03% to 0.1% Ta_2O_5, and about 130 Mt of ore grading in the range of 0.4% to 1% Nb_2O_5, with some zones in the range of 1% to 1.5% Nb_2O_5. Mineralogy of the area was said to be complex and mineral processing problems remain to be addressed (Mining Journal, 2000a).

Japan.—In 2000, Japan's demand for tantalum was about 552 t; powder, 269 t; compounds,157 t; and products, 126 t. Demand for tantalum powder was met by imports from China, Thailand, the United States, and domestic production from imported potassium fluotantalate. Imports of potassium fluotantalate totaled about 1,140 t, sufficient for the production of about 378 t of tantalum powder. Production of tantalum powder for the electronics sector was about 386 t. Demand for tantalum wire used in tantalum capacitors was met entirely by imports, about 68 t, mostly from the United States. Tantalum imports (powder, compounds, and products) in 2000 were about 139 t compared with about 98 t in 1999. In 2000, apparent consumption of tantalum powder, wire, and products was 269 t, 69 t, and 57 t, respectively. In 2001, tantalum demand is forecast to fall to about 462 t; powder, 225 t; compounds, 127 t; and products, 110 t (Roskill's Letter from Japan, 2001b). Tantalum scrap imported for the production of tantalum powder, compounds, and products was about 203 t; Portugal, the United Kingdom, and the United States accounted for about 75% of the imports. In 2000, Japan's production of tantalum capacitors totaled about 8.67 billion units compared with about 6.54 billion units in 1999. Tantalum capacitor exports in 2000 were about 3.24 billion units compared with about 2.56 billion units in 1999 (Roskill's Letter from Japan, 2001a).

Russia.—At yearend 1999, the Chita region made a decision to join a federal program named Libton for the creation of a scientific production center for rare metals, including tantalum, in the Trans-Baikal region. The Chita region and TVEL, a producer and supplier of nuclear fuel controlled by the Russian Ministry of Atomic Energy, signed an agreement on liaison with the Priargunsky Mining and Chemicals Production Association, a uranium producer controlled by TVEL, and the Zabaikalsky Mining and Beneficiation Plant, a rare metal producer. The Ministry was to finance the program and coordinate efforts by Priargunsky and Zabaikalsky to produce materials for the nuclear sector (Interfax International Ltd., 2000).

Outlook

Columbium.—The principal use for columbium will continue as an additive in steelmaking, mostly in the manufacture of microalloyed steels used for pipelines, bridges, automobiles, etc. The production of high-strength low-alloy steel is the leading use for columbium, and the trend for columbium demand, domestically and globally, will continue to follow closely that of steel production (see the "Outlook" section of the Iron and Steel chapter for a discussion of the future of the steel industry). The October 2000 medium-term forecast of the International Iron and Steel Institute projected an annual growth rate in steel consumption between 2000 and 2005 for the world of 2%; the North American Free Trade Agreement countries, 0.9%; European Union countries, 0.8%; China, 3.8%; and total Asian countries, 2.6%. Japan was the only major steel consumer where steel usage was expected to fall, by about 1% (International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth—Annual report of the Secretary General, accessed June 1, 2001, at URL http://www.worldsteel.org/trends_indicators/demand.html).

The outlook for columbium also will be dependent on the performance of the aerospace industry and the use of columbium-bearing alloys in it. Columbium consumption in the production of superalloys, which is the second largest end use for columbium, will be most dependent on the market for aircraft engines. Because nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of engine weight, they are expected to be the materials of choice for the future owing to their high temperature operating capability (Tantalum-Niobium International Study Center, 1999b). The Aerospace Industries Association (2001, p. 3) forecast that U.S. aerospace industry

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sales will rise to $145 billion in 2001 from $144 billion in 2000 owing to the strength of Department of Defense increases.

The majority of U.S. demand for columbium units will continue to be met by imports. Brazil will continue as the leading source for U.S. imports of columbium, and Canada will also be a major source of supply.

Tantalum.—U.S. apparent consumption of tantalum totaled about 650 t in 2000 compared with about 555 t in 1999. More than 60% of the tantalum consumed was used to produce electronic components, mainly tantalum capacitors. This market sector is expected to be stimulated by the growth in the use of cellular telephones; each phone may contain from 10 to 20 capacitors (Mining Journal, 2000b). Tantalum consumption in superalloys, mostly in the aircraft industry, is expected to grow by about 3% per year. Tantalum carbide in the metal cutting industry and tantalum in the chemical processing industry will be dependent on the growth of the general economy, and both are expected to grow at an estimated 2% per year (Tantalum-Niobium International Study Center, 1998).

In 2000, world tantalum supply was estimated to be about 1.8 Mt of contained tantalum. For 2001, world tantalum supply was projected to be about 2.1 Mt of contained tantalum. World tantalum supply will come mostly from Australia, Brazil, Canada, China, Southeast Asia, and certain African countries (including Burundi, Congo (Kinshasa), Ethiopia, Mozambique, Nigeria, Rwanda, Uganda, and Zimbabwe) (Tantalum-Niobium International Study Center, 2001). Another important component of world supply is the U.S. Government sales of tantalum materials from the NDS. As of June 30, 2001, tantalum materials authorized for disposal from the NDS totaled about 910 t of contained tantalum, including about 860 t contained in tantalum minerals.

References Cited

Aerospace Industries Association Update, 2001, AIA projects rise in aerospace sales: Aerospace Industries Association Update, v. 5, no. 7, January-February, 7 p.

American Metal Market, 2000, New plant allows CBMM to hike ferrocolumbium yield: American Metal Market, v. 108, no. 117, June 19, p. 12.

Avalon Ventures, Ltd., 2000a, Drilling set to begin at Lilypad Lakes tantalum project, Pickle Lake, Ontario: Toronto, Avalon Ventures, Ltd. news release, November 13, 1 p.

———2000b, Funding arranged and new work program initiated on Avalon's three tantalum exploration projects: Toronto, Avalon Ventures, Ltd. news release, September 11, 2 p.

Cambior Inc., 2001, Annual report—2000: Longueuil, Quebec, Cambior Inc., 64 p.

Cunningham, L.D., 1999a, Columbium (Niobium), *in* Plunkert, P.A., and Jones, T.S., comps., Metal prices in the United States through 1998: U.S. Geological Survey, p. 35-38.

———1999b, Tantalum, *in* Plunkert, P.A., and Jones, T.S., comps., Metal prices in the United States through 1998: U.S. Geological Survey, p. 143-145.

Defense National Stockpile Center, 2001a, FY 2001 revised annual materials plan and FY 2002 annual materials plan sent to Congress: Fort Belvoir, VA, Defense National Stockpile Center news release, February 22, 4 p.

———2001b, Revised FY 2001 annual materials plan: Fort Belvoir, VA, Defense National Stockpile Center news release, April 9, 2 p.

Interfax International, 2000, TVEL completes mine construction at tantalum deposit: Mining & Metals Report, v. 9, issue 40 (445), September 29-October 5, p. 15, 16.

KEMET Corp., 2000a, KEMET announces joint venture with Australasian Gold Mines NL: Greenville, SC, KEMET Corp. news release, November 15, 1 p.

———2000b, KEMET to add an additional 85,000 square feet for the manufacture of tantalum surface-mount capacitors: Greenville, SC, KEMET Corp. news release, July 26, 1 p.

———2001, KEMET completes joint venture agreement with Australasian Gold Mines NL: Greenville, SC, KEMET Corp. news release, February 6, 1 p.

Mining Journal, 1999a, Niobium: Mining Journal, Steel Industry Metals Annual Review Supplement, v. 333, no. 8543, August 6, p. 78.

———1999b, Tantalum: Mining Journal, Speciality Metals Annual Review Supplement, v. 333, no. 8544, August 13, p. 89.

———2000a, Greenland tantalum venture: Mining Journal, v. 334, no. 8569, February 11, p. 113.

———2000b, Tantalum comes of age: Mining Journal, v. 334, no. 8583, May 19, p. 391, 393.

Platt's Metals Week, 2000, China tantalum expansion complete: Platt's Metals Week, v. 71, no. 36, p. 13.

Roskill's Letter from Japan, 2001a, Tantalum—Powder prices rise by 60%: Roskill's Letter from Japan, no. 297, May, p. 10-12.

———2001b, Tantalum—Slow-down in demand forecast for 2001 following two years of growth: Roskill's Letter from Japan, no. 298, June, p. 3-6.

Skillings Mining Review, 2000, Avalon in tantalum JV agreement: Skillings Mining Review, v. 89, no. 43, October 21, p. 17.

Sons of Gwalia Ltd., 2000, Annual report—2000: West Perth, Western Australia, Sons of Gwalia Ltd., 79 p.

———2001, Quarterly report for three months ending 31 March 2001: West Perth, Western Australia, Sons of Gwalia Ltd., 15 p.

Tantalum-Niobium International Study Center, 1998, Tantalum supply and demand: Tantalum-Niobium International Study Center, no. 96, December, 12 p.

———1999a, Overview of the tantalum and niobium industries for 1998 and 1999: Tantalum-Niobium International Study Center, no. 100, December, 12 p.

———1999b, Technical and commercial development of the European niobium market: Tantalum-Niobium International Study Center, no. 98, June, 8 p.

———2001, Tantalum—Raw material supply: Tantalum-Niobium International Study Center, no. 105, March, 8 p.

Teck Corp., 2001, Annual report—2000: Vancouver, Teck Corp., 82 p.

TEX Report, 2000, CBMM/Brazil completes capacity expansion for niobium in May: TEX Report, v. 32, no. 7541, April 26, p. 1.

United Nations, 2001, Letter dated 12 April 2001 from the Secretary-General to the President of the Security Council: United Nations, Security Council, 56 p.

U.S. Customs Service, 2000, Renewal of the Generalized System of Preferences: Federal Register, v. 65, no. 42, March 2, p. 11367, 11368.

U.S. Department of Defense, 2001, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 1999 through September 2000: Washington, DC, U.S. Department of Defense, 54 p.

U.S. International Trade Commission, 1999, Harmonized tariff schedule of the United States—2000: Washington, DC, U.S. Government Printing Office, U.S. International Trade Commission Publication 3249, variously paginated and unpaginated.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Columbium (Niobium). Ch. in Mineral Commodity Summaries, annual.

Columbium (Niobium) and Tantalum. Ch. in Minerals Yearbook, annual.

Columbium (Niobium) and Tantalum. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Columbium (Niobium) and Tantalum. Mineral Industry Surveys, annual.

Niobium (Columbium) and Tantalum. International Strategic Minerals Inventory Summary Report, Circular 930-M, 1993.

Tantalum. Ch. In Mineral Commodity Summaries, annual.

Other

Aerospace Industries Association.

American Metal Market, daily.

Chemical and Engineering News, weekly.

Columbium (niobium). Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Company annual reports.

Defense National Stockpile Center stockpile reports and news

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releases.
Electronic Industries Alliance.
Engineering and Mining Journal, monthly.
Federal Register, daily.
Metal Bulletin (London), semiweekly and monthly.
Metal Bulletin Books Ltd.:
Ferroalloy Directory and Data Book, 5th ed., 1998.
Ores & Alloys for the Global Steel Industry, 2000.
Mining Journal (London), weekly.
Platt's Metals Week, weekly.
Roskill Information Services Ltd. Reports (London):
The Economics of Niobium, 8th ed., 1998.
The Economics of Tantalum, 7th ed., 1999.
Roskill's Letter from Japan, monthly.
Ryan's Notes, weekly.
Skillings Mining Review.
Tantalum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Tantalum-Niobium International Study Center (Brussels):
International Symposium-Proceedings.
Quarterly Bulletin.
The Northern Miner.
The TEX Report (Tokyo: daily issues and annual ferroalloy manual).

TABLE 1
SALIENT COLUMBIUM STATISTICS 1/

(Metric tons of columbium content unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Government stockpile releases 2/	30	126	145	280	217
Production of ferrocolumbium	NA	NA	NA	NA	NA
Exports, columbium metal, compounds, alloys gross weight	NA	NA	NA	NA	NA
Imports for consumption:					
Mineral concentrates e/	285	220	200	140	300
Columbium metal and columbium-bearing alloys e/	322	423	563	468	607
Columbium oxide	630	1,220	860	1,200	1,190
Ferrocolumbium e/	2,970	4,260	4,900	4,450	4,400
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium e/	3,380	3,770	3,640	3,460 r/	4,090
Apparent e/	3,830 r/	4,030 r/	4,150 r/	4,100 r/	4,300
Prices:					
Columbite 3/ dollars per pound	$3.00	$3.00	$3.00	$3.00	$6.25
Pyrochlore 4/ do.	NA	NA	NA	NA	NA
World, production of columbium-tantalum concentrates e/	16,200	20,600 r/	26,200	32,600 r/	32,600

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Net quantity (uncommited inventory).
3/ Yearend average value, contained pentoxides for material having a columbium pentoxide to tantalum pentoxide ratio of 10 to 1.
4/ Yearend average value, contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

(Metric tons of tantalum content unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Government stockpile releases 1/	34	20	213 r/	5 r/	242
Exports:					
Tantalum ores and concentrates 2/ gross weight	53	91	389	299	263
Tantalum metal, compounds, alloys do.	342	396	423	460	460
Tantalum and tantalum alloy powder do.	26	58	61	90	108
Imports for consumption:					
Mineral concentrates e/	360	280	380	320	650
Tantalum metal and tantalum-bearing alloys 3/	203	187	208	244	251
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Apparent e/	524 r/	570 r/	738 r/	555 r/	650
Price, tantalite 4/ dollars per pound	$27.75	$33.00 r/	$34.00 r/	$34.00	$160.00
World, production of columbium-tantalum concentrates e/	436 r/	492 r/	571 r/	569 r/	836

See footnotes at end of table.

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TABLE 2--Continued
SALIENT TANTALUM STATISTICS

e/ Estimated. r/ Revised. NA Not available.
1/ Net quantity (uncommited inventory).
2/ Includes reexports.
3/ Exclusive of waste and scrap.
4/ Yearend average value, contained pentoxides.

TABLE 3
COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT INVENTORIES AS OF DECEMBER 31, 2000 1

(Metric tons of columbium or tantalum content)

Material	Stockpile goals	Disposal authority	National Defense Stockpile inventory			
			Uncommitted			
			Stockpile grade	Nonstockpile grade	Total	Committed
Columbium:						
Concentrates	--	528	285	244	528	138
Carbide powder	--	10	10	--	10	--
Ferrocolumbium	--	52	52	--	52	37
Metal ingots	--	46	46	--	46	9
Total	--	636	392	244	636	185
Tantalum:						
Minerals	--	778	453	325	778	198
Carbide powder	--	6	6	--	6	2
Metal:						
Capacitor grade	(2/)	23	39	(3/)	39	--
Ingots	(2/)	12	67	--	67	15
Oxide	--	37	37	--	37	--
Total	71 2/	856	601	325	926	215

-- Zero.
1/ Data may not add to totals shown because of independent rounding.
2/ Goals as of October 5, 1999; about 16 tons for tantalum metal powder, and about 55 tons for tantalum metal.
3/ About 60 kilograms.

Source: Defense National Stockpile Center.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES 1/

(Metric tons of contained columbium)

End use	1999	2000
Steel:		
Carbon	1,270	1,370
Stainless and heat-resisting	603	682
Full alloy	(2/)	(2/)
High-strength low-alloy	938 r/	1,090
Electric	(2/)	(2/)
Tool	(2/)	(2/)
Total	2,810 r/	3,140
Superalloys	641 r/	942
Alloys (excluding alloy steels and superalloys)	(3/)	(3/)
Miscellaneous and unspecified	9	10
Grand total	3,460 r/	4,090
Stocks, December 31:		
Consumer	NA	NA
Producer 4/	NA	NA
Total	NA	NA

r/ Revised. NA Not available. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Included with "Steel: High-strength low-alloy."
3/ Included with "Miscellaneous and unspecified."
4/ Ferrocolumbium only.

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TABLE 5
U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS 1/

Class	1999 Gross weight (metric tons)	1999 Value (thousand dollars)	2000 Gross weight (metric tons)	2000 Value (thousand dollars)	Principal destinations and sources, 2000 (gross weight, metric tons, thousand dollars)
Exports: 2/					
Columbium:					
Ores and concentrates	12	566	55	830	Germany 30, $293; Belgium 2, $218; Switzerland 4, $131; Republic of Korea, 7, $51; Japan 5, $51; China 4, $43.
Ferrocolumbium	166	1,110	60	526	Mexico 51, $408; United Kingdom 6, $96; Canada 3, $22.
Tantalum:					
Synthetic concentrates	18	129	91	174	Japan 14, $101; Venezuela 18, $33; Hong Kong 57, $28; Germany 1, $10; Hungary 1, $3.
Ores and concentrates	299	7,150	263	11,400	China 218, $10,000; Kazakhstan 7, $823; Netherlands 13, $290; Brazil 23, $244; France 1, $17; Japan 1, $13.
Unwrought and waste and scrap	233	11,100	198	16,000	United Kingdom 35, $4,280; Germany 31, $3,380; Austria 12, $1,930; China 15, $1,850; Hong Kong 86, $1,670; Australia 6, $1,280.
Unwrought powders	90	31,900	108	43,100	Israel 88, $36,900; Germany 6, $2,140; Japan 4, $1,630; Austria 5, $1,030; France 2, $565; United Kingdom 1, $332; Sweden 1, $311.
Unwrought alloys and metal	95	22,000	123	40,100	United Kingdom 36, $18,300; Isreal 55, $14,800; France 17, $2,740; Germany 5, $2,110; Barbados 2, $771; Brazil 2, $707.
Wrought	132	43,500	139	47,500	Japan 52, $20,500; Germany 32, $11,000; United Kingdom 10, $5,080; France 10, $2,840; Sweden 3, $1,180; Canada 4, $855.
Total	XX	118,000	XX	160,000	Israel $52,400; United Kingdom $28,100; Japan $22,400; Germany $18,900; China $12,800; France $6,170; Austria $3,580; Hong Kong $1,730.
Imports for consumption:					
Columbium:					
Ores and concentrates	95	1,620	151	1,680	China 117, $1,320; Beligium 9, $155; Brazil 17, $154; Nigeria 7, $47; Germany 1, $3.
Oxide	1,720	30,600	1,700	29,200	Brazil 682, $10,600; Germany 203, $7,610; China 335, $4,180; Russia 244, $3,620; Estonia 190, $2,510; Japan 30, $480.
Ferrocolumbium	6,850	62,200	6,770	62,100	Brazil 5,660, $50,500; Canada 928, $9,650; France 126, $1,000; Germany 55, $901.
Unwrought alloys, metal and powder	468	13,500	606	16,900	Brazil 249, $6,440; Estonia 153, $5,790; Germany 157, $3,490; China 38, $641; Kazakhstan 8, $316; Canada 1, $168.
Tantalum:					
Ores and concentrates	992	33,600	2,080	74,800	Australia 1,280, $41,600; Nigeria 287, $15,800; Canada 178, $6,940; Congo (Kinshasa) 3/ 167, $4,720; Rwanda 68, $2,180; Ethiopia 21, $2,020; China 48, $828.
Unwrought waste and scrap	809	14,500	853	31,400	United Kingdom 268, $10,300; Austria 36, $4,210; Japan 87, $3,410; Taiwan 54, $2,380; Israel 230, $2,190; China 52, $2,140; Kazakhstan 16, $1,520.
Unwrought powders	165	49,800	177	66,900	Japan 64, $36,300; Thailand 57, $15,300; China 47, $13,200; Germany 9, $1,930; France 1, $250; United Kingdom (4/), $31.
Unwrought alloys and metal	23	4,110	31	5,610	Kazakhstan 19, $2,430; Germany 8, $2,200; Russia 1, $246; Canada 1, $226; Brazil 1, $118; China (4/), $114.
Wrought	56	13,000	43	14,900	China 32, $9,590; Japan 5, $2,820; Germany 1, $767; Austria 1, $404; Canada 2, $398; United Kingdom (4/), $260.
Total	XX	223,000	XX	303,000	Brazil $67,800; Japan $43,200; Australia $41,600; China $32,000; Germany $18,300; Canada $17,400; Nigeria $15,800; Thailand $15,30

XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.
3/ Formerly Zaire.
4/ Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1999		2000	
	Gross weight (metric tons)	Value (thousand dollars)	Gross weight (metric tons)	Value (thousand dollars)
Belgium 2/	--	--	9	155
Brazil	--	--	17	154
China	75	1,320	117	1,320
Germany 2/	--	--	1	3
Nigeria	--	--	7	47
Russia	20	291	--	--
Total	95	1,620	151	1,680

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Presumably country of transshipment rather than original source.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1999		2000	
	Gross weight (metric tons)	Value (thousand dollars)	Gross weight (metric tons)	Value (thousand dollars)
Australia	597	20,100	1,280	41,600
Belgium 2/	--	--	4	62
Bolivia	11	395	1	45
Burundi	7	186	--	--
Canada	173	6,440	178	6,940
China	3	206	48	828
Congo (Kinshasa) 3/	81	2,000	167	4,720
Ethiopia	20	1,540	21	2,020
Nigeria	8	549	287	15,800
Russia	--	--	1	86
Rwanda	59	1,270	68	2,180
South Africa	--	--	1	23
Tanzania	9	169	15	377
Uganda	24	645	5	140
United Kingdom 2/	(4/)	17	--	--
Total	992	33,600	2,080	74,800

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Presumably country of transshipment rather than original source.
3/ Formerly Zaire.
4/ Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
Do.	Sons of Gwalia Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM) (Araxa)	Columbium.
Do.	Cia. de Estanho Minas Brasil (MIBRA) 1/	Columbium-tantalum.
Do.	Paranapanema S.A. Mineracao Indústria e Construcao (Pitinga)	Do.
Do.	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior Inc., and Teck Corp. (Niobec)	Do.
Do.	Tantalum Mining Corp. of Canada Ltd. (Tanco) 2/	Tantalum.
China	Government-owned	Columbium-tantalum.

See footnotes at end of table.

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TABLE 8--Continued
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Do.
Brazil	Cia. Industrial Fluminense 1/	Do.
Do.	Mamoré Mineracao e Metalurgia 3/	Do.
Thailand	Thailand Smelting and Refining Co., Ltd. (Thaisarco)	Do.
Production capacity for columbium- and tantalum-bearing synthetic concentrates, Germany, western states	H.C. Starck GmbH & Co. KG	Do.

1/ A wholly owned subsidiary of Metallurg Inc., New York, NY.
2/ A wholly owned subsidiary of Cabot Corp.
3/ A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products 1/
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, NiNb.
	Cia. Industrial Fluminense 2/	Nb and Ta oxide.
	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Canada	Cambior Inc., and Teck Corp. (Niobec)	Do.
Estonia	Silmet	Nb oxide/metal.
Germany, western states	Gesellschaft fuer Elektrometallurgie mbH (GFE) 2/	FeNb, NiNb.
	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb NiNb, Ta capacitor powder.
Japan	Mitsui Mining and Smelting Co. Ltd.	Nb and Ta oxide/metal/carbide.
	Showa Cabot Supermetals 3/	Ta capacitor powder.
	H.C. Starck-V Tech Ltd. 4/	Do.
Kazakhstan	Ulba Metallurgical	Ta oxide/metal.
	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd. 4/	K-salt, Ta metal.
United States	Cabot Performance Materials	Nb and Ta oxide/metal, K-salt, Ta capacitor powder.
	H.C. Starck Inc. 5/	Nb and Ta metal, Ta capacitor powder.
	Kennametal Inc.	Nb and Ta carbide.
	Reading Alloys Inc.	FeNb, NiNb.
	Shieldalloy Metallurgical Corp. 2/	FeNb.
	Wah Chang 6/	Nb metal, FeNb.

1/ Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
2/ A wholly owned subsidiary of Metallurg Inc., New York.
3/ A joint venture between Showa Denko and Cabot Corp.
4/ A subsidiary of H.C. Starck GmbH & Co. KG.
5/ Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.
6/ A subsidiary of Allegheny Technologies Inc.

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TABLE 10
COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

	Gross weight 3/					Columbium content 4/					Tantalum content 4/				
Country 5/	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Australia, columbite-tantalite	920	1,010	1,150	1,230	1,600	112	125	140	140	160	276	302	330	350	485
Brazil:															
Columbite-tantalite	190	190	330	330	330	45	45	70	70	70	55	55	90	90	90
Pyrochlore	32,600	42,900	56,200	71,200 r/	71,400	13,700	18,000	23,600	29,900 r/	30,000	--	--	--	--	--
Burundi	37	46	30	42	42	NA	NA	NA	NA	NA	9	11	7	10	10
Canada:															
Pyrochlore	5,160	5,090	5,110	5,240	5,070	2,320	2,990	2,300	2,360	2,280	--	--	--	--	--
Tantalite	220	196	228	208	228	11	10	11	10	11	55	49	57	54 r/	57
Congo (Kishasa), columbite-tantalite	NA r/	NA r/	NA r/	NA r/	450	NA r/	NA r/	NA r/	NA r/	NA	NA r/	NA r/	NA r/	NA r/	130
Ethiopia, tantalite	20	20	40	50	65	2	2	4	5	7	12	12	24	29	38
Nigeria, columbite	57 6/	60	70	70	80	23	23	30	30	35	3	3	3	3	4
Rwanda	97	224	224	122	83	33	76	76	42	28	26	60	60	33	22
Total	39,300 r/	49,700 r/	63,400 r/	78,500 r/	79,300	16,200	20,600 r/	26,200	32,600 r/	32,600	436 r/	492 r/	571 r/	569 r/	836

r/ Revised. NA Not available. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Excludes columbium- and tantalum-bearing tin ores and slags. Production of tantalun contained in tin slags was, in metric tons: 1996--82; 1997--40; 1998-2000--NA according to data from the Tantalum-Niobium International Study Center. Table includes data available through July 9, 2001.

3/ Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of comlumbium, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

4/ Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

5/ In addition to the countries listed, Bolivia, China, Russia, and Zambia also produce or are believed to produce columbium and tantalum mineral concentrates, but information is inadequate to make reliable estimates of output levels.

6/ Reported figure.

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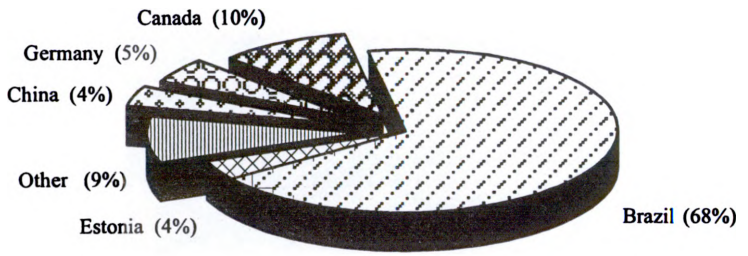
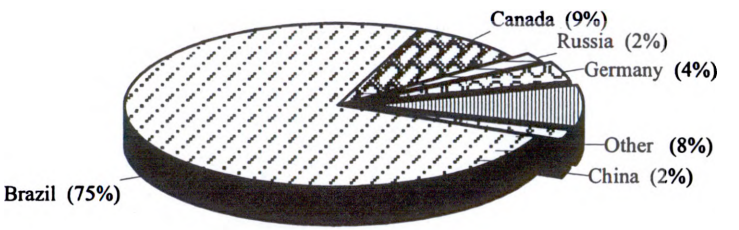
FIGURE 1

MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium content)



2000

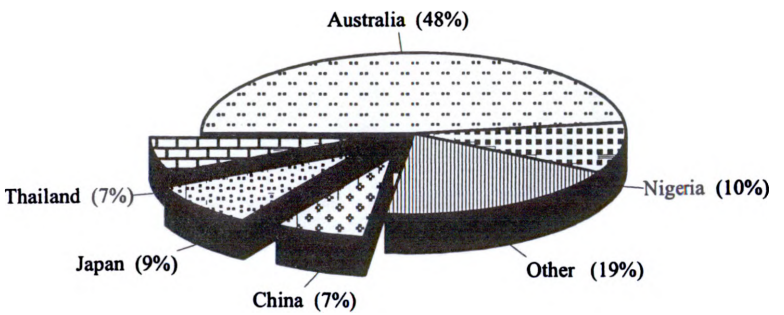


1997 - 2000

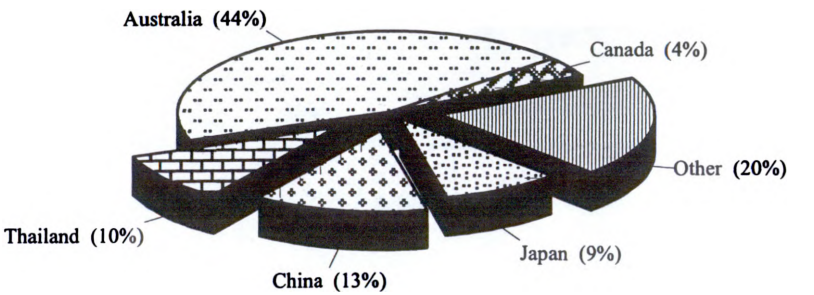
FIGURE 2

MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum content)



2000



1997 - 2000

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COPPER

By Daniel L. Edelstein

Domestic survey data and tables were prepared by Janet D. Richards and Deana Demichelis, statistical assistants, and the world production tables were prepared by Regina R. Coleman, Linder Roberts, and Glenn J. Wallace, international data coordinators.

In 2000, mine production of recoverable copper in the United States continued its downward slide that began in 1998, falling by more than 150,000 metric tons (t) to the lowest level since 1988. In addition to mine closures and cutbacks carried forward from midyear 1999, high energy costs coupled with low copper prices led to unanticipated cutbacks and closures. Some rationalization of capacity occurred following consolidation of ownership at the end of 1999. Three companies, Phelps Dodge Corp., ASARCO Inc. (owned by Mexico's Grupo Mexico S.A. de C.V.), and Kennecott Utah Copper Corp. (owned by Rio Tinto plc of the United Kingdom), accounted for more than 95% of U.S. copper mine production.

While the United States maintained its position as the world's second largest mine producer of copper, accounting for about 11% of world production, its share of global production continued to decline from its 19% share in 1994. Chile, where mine production increased by 5% in 2000, and by 85% since 1995, was the largest mine producer and accounted for 35% of world production. World mine production grew by about 3.5% in 2000 and by 30% since 1995. The world reserves and reserve base for copper were estimated to be 340 million metric tons (Mt) and 650 Mt, respectively. The United States had about 13% each of reserves and reserve base. In the 1998 National Mineral Resource Assessment conducted by the U.S. Geological Survey (U.S. Geological Survey, 2000), the estimated copper contained in undiscovered resources in the United States ranged from greater than 170 Mt at a 90% probability to greater than 440 Mt at a 10% probability. The mean estimate of copper in undiscovered deposits was 290 Mt. According to the assessment, more than two-thirds of the copper was thought to be contained in undiscovered porphyry copper deposits. Other major deposit types were sediment-hosted and volcanogenic massive sulfide deposits. About 50% of the undiscovered resource was believed to be in Great Basin and Southern Basin and Range regions (portions of Arizona, California, Nevada, New Mexico, and Utah). The identified copper resource was estimated to be 260 Mt. Coupled with past production of about 91 Mt, the total discovered copper resource in the United States was estimated to be 350 Mt.

U.S. copper smelter and refinery production also continued to fall and were down by 23% and 16%, respectively, from 1999 production levels, and 42% and 33%, respectively, from production in 1998. Owing to the combined impact of mine cutbacks and low prices, three of seven primary smelters had closed in 1999. Primary refined production declined owing to a downstream shortage of anode for refining. With the three smelters remaining closed in 2000, the United States became a net exporter of copper in concentrates. Contraction of the secondary copper industry continued with the closure in May of one of the Nation's two remaining secondary smelters and its

Copper in the 20th Century

At the beginning of the 20th century, following patenting of the electric lightbulb and initial development of electric power distribution infrastructure late in the 19th century, the United States was experiencing a prolonged period of expansion in copper use for electrical generation, distribution, and industrial applications. U.S. mine production rose from 27,000 metric tons in 1880 to 275,000 tons in 1900 and 490,000 tons in 1910. Most of the copper produced came from high-grade vein deposits that predominantly yielded ore for direct shipping to smelters (80 smelters operated in 1907). By 1900, Montana and Arizona had emerged as the leading producing States, accounting for 45% and 20% of domestic production, respectively. The United States was by far the world's largest producer in 1900, accounting for 55% of world production and exporting about 160,000 tons of refined copper and consuming about 160,000 tons.

The United States retained its position as the largest producer and consumer of copper through most of the century. Domestic copper mine production peaked in 1997 at 1.94 million tons. Froth flotation and large-scale open pit mining methods introduced during the first decade of the century had revolutionized copper mining, and production was derived increasingly from low-grade porphyry copper deposits. Industrialization, rural electrification, and growing infrastructure all contributed to the growth in copper demand. Electrical applications accounted for an increasing share of domestic consumption (about 75% in 2000).

By the start of the 21st century, however, the United States had relinquished its role as the world's largest copper producer to Chile (35% of global production). U.S. mine production in 2000 fell to about 1.4 million tons and accounted for only about 11% of world production. Technology advances made in the 1980s resulted in one-third of U.S. mine output in 2000 coming from the leaching and solvent extraction-electrowinning of acid soluble ores. The combined impact of environmental regulation and industry restructuring left only four smelters operating. The United States remained the world's largest user of refined copper (about 3 million tons, 20% of world total) and was dependant on imports for about one-third of its refined copper supply. Copper recovered from old scrap (500,000 tons in 1997) also fell victim to industry consolidation and offshore processing and declined to only 350,000 tons in 2000.

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captive electrolytic refinery. Electrowon production, which accounted for a record 36% of primary refined production and 38% of mine production, declined by about 5%. Though it retained its position as the second largest refiner and third largest smelter, the U.S. share of world smelter and refinery production fell to 9% and 12% , both down from 15% in 1998. In 1998, the United States had been the largest smelter and refiner of copper.

Twenty-seven mines operating in 7 States, down from 33 in 1999, reported recoverable quantities of copper in 2000. Fourteen mines located in Arizona, Utah, New Mexico, and Montana, in descending order, accounted for more than 99% of production. The remaining 13 mines were either small leach operations or byproduct producers of copper. Despite the decline in production, capacity utilization at domestic mines rose, as capacity was adjusted downward to reflect the long-term closure of mines that were not expected to reopen without significant capital investment.

During the year, 4 primary and 2 secondary smelters, 6 electrolytic and 3 fire refineries, and 14 solvent extraction-electrowinning (SX-EW) facilities operated in the United States. By yearend, however, one secondary smelter and associated electrolytic refinery had closed. Following closure of three primary smelters in 1999, which were not anticipated to reopen in the short term, smelter capacity for 2000 was revised downward from 1.75 million metric tons per year (Mt/yr) in 1999 to 1.18 Mt/yr. Consequently, smelter capacity utilization rose from 74% in 1999 to 85% in 2000. Capacity at refineries declined by about 200,000 metric tons per year (t/yr) to 2.4 Mt/yr and the utilization rate fell to 74%. The conversion of old scrap to alloys and refined copper, declined by 47,000 t (12%), contributed 334,000 t of copper to the market, and accounted for 11% of apparent industrial demand. Lower copper prices in 2000 and closure of a secondary copper smelter led to the continued downward trend in recovery.

Copper was consumed as refined copper and as direct melt scrap at about 35 brass mills, 13 wire-rod mills, and 600 foundries, chemical plants, and miscellaneous operations. According to data compiled by the Copper Development Association Inc. (CDA) (Copper Development Association, Inc., 2001, p. 18), mill and foundry product shipments to the U.S. market, including net imports of mill products, continued their upward trend, rising by170,000 t (4%) to 4.33 Mt, and were 43% higher than shipments in 1990.

The net import reliance for refined copper, as a percentage of apparent consumption, rose sharply to a record-high 37% (from 14% in 1998) following cutbacks in domestic production and growth in demand. Peru emerged as the largest source of refined copper, and, along with Canada and Chile, accounted for about 80% of refined imports. Canada remained the largest U.S. source for unwrought copper, accounting for 27% of total imports of unwrought copper. China (including Hong Kong), owing to a large growth in U.S. scrap exports, became the largest recipient for unwrought exports, accounting for 58% of refined exports and 38% (copper content) of total exports.

Legislation and Government Programs

On January 26, 2000, as authorized by the Coin Act of 1997, the U.S. Mint began releasing its new Golden dollar coin to replace the Susan B. Anthony dollar coin that had been introduced in 1979. In its report to Congress, the Mint outlined details of a promotional campaign aimed at helping the public build a strong awareness for the coins. According to the Mint, about 700 million Golden Dollars were placed in circulation during 2000, 7 times initial expectations. The new coins also generated an $800 million profit for the Mint (U.S. Mint, 2001). At a coin weight of 8.1 grams and overall composition of 88.5% copper, 6% zinc, 3.5% manganese, and 2% nickel, the 700 million coins contained about 5,000 t of copper.

In January, the U.S. Department of Labor, Division of Trade Adjustment and Assistance, rejected a petition by the United Steel Workers of America seeking transitional adjustment assistance for workers producing copper rod at the Pauline, KS, plant of Superior-Essex Inc. In rejecting the petition, the department found that criterion 3 (the subject firm increased imports of like products from Canada or Mexico) and criterion 4 (the firm shifted production to Canada or Mexico) of the act had not been met. The Division of Trade Adjustment and Assistance concluded that copper rod production at Pauline had been shifted to other domestic plants of the subject firm and that Superior-Essex had neither increased its imports from Mexico or Canada nor shifted production to those countries (U.S. Department of Labor, 2000).

In June, the U.S. Environmental Protection Agency (EPA) proposed a change to its proposed national emissions standards for hazardous air pollutants (NESHAP) for primary smelters (smelting furnaces, slag cleaning furnaces, and batch converters). In April 1998, under section 112 of the Clean Air Act, which directs EPA to establish NESHAPs to control emissions from major stationary sources, EPA had proposed an equipment-based standard. The new proposed rule for the control of process emissions would establish a numerical emissions standard for particulate matter of 23 milligrams of total particulate matter per dry standard cubic meter (0.010 grains per dry standard cubic foot). In EPA's judgment, the proposed standard reflects "a level of total particulate matter emissions that can be achieved consistently by a properly operated and maintained sulfuric acid plant used to control process offgas from primary smelting and converting operations." The proposed standard also specifies that a furnace will be in violation of the standard if leak detector alarms installed on baghouses indicate higher than allowable emissions more than 5% of the operating time over a 6-month period. Copper smelting was 1 of 170 categories selected for regulation under the Clean Air Act (U.S. Environmental Protection Agency, 2000b).

In November, in response to an industry petition, EPA issued a final rule exempting the need for a residue tolerance test, in accordance with the Federal Food, Drug, and Cosmetic Act (as amended by the Food Quality Protection Act of 1996), when copper sulfate pentahydrate is used as a fungicide on raw agricultural commodities after harvest. This regulation eliminates the need to establish a maximum permissible level for residues of copper sulfate pentahydrate. While use of copper compounds has been exempted from tolerance tests when applied to growing crops, they had not been exempted when applied to crops at the time of or after harvest. Copper compounds are already exempted from testing when used on harvested fish, meat, poultry, eggs, and irrigated crops. In granting its exception, EPA noted relevant scientific data indicating that it is unlikely that excessive amounts of copper

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ion from this use would be ingested, that copper is ubiquitous in nature and naturally occurring in ingested water and plants, is an essential nutritional element in animals (including humans) and plants, not readily absorbed when ingested, and that most of absorbed copper is excreted (U.S. Environmental Protection Agency, 2000a).

Production

Mine production capacity was adjusted downward by about 250,000 t/yr to about 1.75 Mt/yr, reflecting the sustained closure of BHP Copper Co. mines and reduced capacity at several other mines that had shifted mining strategies or plans. Phelps Dodge closed its Metcalf concentrator at its Morenci Mine in Arizona during August in anticipation of switching to an all leach operation in 2001. In response to lower average prices, mine closures, and higher than anticipated utility rates, production declined by about 160,000, t and capacity utilization rose slightly to about 84%. With the exception of its small Arizona leach SX-EW operations at San Manuel, Pinto Valley, and Miami, BHP's mines remained shuttered.

Primary smelter production declined by 21% following the closure of three of the seven primary domestic smelters during 1999 and was down by 42% from that in 1998. Smelter capacity was revised downward to reflect the indefinite closure of these smelters. Secondary smelter production continued its downward trend, declining by 31%. In May, Southwire Co. closed its secondary smelter and associated electrolytic refinery, in Carrollton, GA. Southwire continued to operate its rod mill housed within its Copper Division Southwire (CDS). Sixteen months prior, as part of a restructuring plan aimed at lowering its costs, Southwire had unsuccessfully placed its Carrollton copper smelter/refinery operations on the market. Southwire cited economic factors, including the continued cost of compliance with environmental regulations in the metro-Atlanta area, for the closure of copper smelting operations. CDS was constructed in 1972, at a time when primary producers exerted greater control over copper prices. As part of the closure justification, Southwire cited the advent of worldwide commodity prices and their own "strong buying position" as leverage in meeting future raw material needs (Southwire Co., 2000). Closure of CDS secondary copper facilities, which have a capacity to produce 140,000 t/yr of refined copper, had a significant impact on the U.S. scrap copper market. Southwire processed a mixture of imported blister and copper scrap at its smelter to produce anode for electrolytic refining. Southwire was one of two remaining secondary smelters in the United States, two other smelters having closed in the preceding 3 years. Southwire closed its other secondary copper smelter in Gaston, SC, at the end of 1994, also citing the high cost of environmental compliance as the reason for closure.

Primary and secondary refinery production declined by 16% and 9%, respectively. The aforementioned smelter closures led to downstream shortages of anode for refining. Electrowon production declined by only about 3% and accounted for a record 36% of primary refined production. The Warrenton fire refinery, which had closed in March 1999, was reopened under different management, mitigating some of the lost secondary refinery capacity.

Following acquisition of the assets of Cyprus Amax Minerals Co. at yearend 1999, Phelps Dodge Corp. reported record copper production of 1.32 Mt, including minority participants share of 235,000 t, from its worldwide operations. U.S. production amounted to 850,000 t. In the United States, production and costs were adversely affected by unusually heavy precipitation during the fourth quarter of the year and high energy costs, including electricity, diesel fuel, and natural gas. According to Phelps Dodge, its domestic electricity costs during the fourth quarter averaged $0.11 per kilowatthour, more than three times their 5-year average cost, and total energy costs rose by $0.08 per pound of copper production, a 65% increase over the comparative 1999 period. Total energy costs increased copper unit costs in 2000 by approximately $0.04 per pound compared with unit costs in 1999. Beginning in the spring of 2000, the impact of a power supply/demand imbalance in California, drought in the Pacific Northwest, and higher natural gas prices caused a shortage of electricity and higher spot market electricity costs. Approximately 27% of Phelps Dodge's electricity requirements in 2000 was purchased on the spot market (Phelps Dodge Corp., 2001a, p. 15-16; 2001b, p. 3).

At its Morenci Mine, production of copper in concentrate declined from 177,000 t to 120,000 t following placement of the Metcalf concentrator on standby in June. In September 1999, Phelps Dodge had announced its intent to reduce production costs by converting all Morenci production to mine-for-leach by early 2001 and permanently shut both the Metcalf and Morenci concentrators. The $220 million conversion proceeded throughout 2000 and was completed during the first quarter of 2001. New facilities included an expanded crushing and conveying system, mobile stackers to disperse the ore on leach piles, expanded solvent extraction facilities, and construction of a new electrowinning tankhouse. Electrowon production in 2000 of 258,000 t was unchanged from that of 1999 (Phelps Dodge Corp., 2001a, p. 3-9).

At its Miami, AZ, leach operations acquired with the purchase of Cyprus Amax, a new mine plan was instituted in June that suspended stripping in a higher cost section of the mine and allowed redistribution of equipment to other Phelps Dodge operations. Production in 2000 of 54,000 t of cathode was not impacted by the mine plan change, though production in 2001 and 2002 was expected to fall by 16,000 t and 39,000 t, respectively. At its newly acquired Bagdad Mine in Arizona, Phelps Dodge reported production of 101,000 t of copper in concentrate and 10,700 t of electrowon copper. Electrowon production at its Tyrone, NM, mine was essentially unchanged at 72,000 t (Phelps Dodge Corp., 2001a, p. 3-9).

In March, Phelps Dodge ended speculation on the fate of its newly acquired Sierrita Mine in Arizona when it announced that it intended to invest $13 million to upgrade the mine ($2.9 million), the crushing and conveying system ($2.5 million), the solvent extraction circuit ($1.3 million), as well as other upgrades and land purchases ($3.0 million) (Platt's Metals Week, 2000c). Production in 2000 amounted to 87,000 t of copper in concentrate and 24,000 t of electrowon copper (Phelps Dodge Corp., 2001a, p. 8).

At its Hidalgo, NM, smelter, closed in September 1999, Phelps Dodge announced its intention to reconfigure the smelter to produce sulfuric acid for its leaching operations. While Phelps Dodge had a near-term surplus of concentrate, the company announced at midyear that it intended to stop exporting surplus concentrates and to stockpile them in anticipation of conversion of Morenci to all leach operation,

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resulting in a future concentrate shortfall. Prior to closure of the Hidalgo smelter, Phelps Dodge had been a net importer of copper concentrates from its South American operations (Phelps Dodge Corp., 2000). In 2000, Phelps Dodge smelters produced 449,000 t of copper. As a result of the upstream curtailment in smelting, Phelps Dodge's refineries in El Paso, TX, and Miami, AZ, operated at only 72% of their combined capacity, producing 427,000 t of copper cathode (Phelps Dodge Corp., 2001a, p. 9).

In July, Asarco, a wholly owned subsidiary of Mexico's Grupo Mexico S.A. de C.V., announced plans to consolidate all corporate functions in Phoenix, AZ, by yearend. Following acquisition by Grupo in November 1999, Asarco had already transferred many of its corporate functions from New York City to Arizona (ASARCO Inc., 2000a). Grupo reported that operating and cost savings from the integration of Asarco and Southern Peru Copper Corp. following acquisition in 1999 amounted to more than $171 million. Asarco's share of mine production declined from 293,000 t in 1999 to 261,000 t in 2000 (Grupo Mexico S.A. de C.V., 2001b).

At Asarco's Ray Operations in Hayden, AZ, production of copper in concentrate and electrowon cathode declined to 99,300 t and 38,800 t, respectively, down from 144,000 t and 40,000 t, respectively, in 1999. The Ray mining unit consists of a 227,000-metric-ton-per-day (t/d) open pit mine with a 27,000-t/d concentrator (Ray) and a 23,500-t/d concentrator (Hayden), a 13,600-t/d silicate leaching system, a low-grade sulfide dump leaching system, and a SX-EW operation. The Hayden oxygen flash smelter, with an annual capacity of 650,000 t/yr of concentrates, produced 191,000 t of copper anode. Asarco's El Paso smelter remained on standby throughout the year, and production at its Silver Bell Mine and SX-EW operation in Arizona declined by about 2,000 t to 18,300 t (Grupo Mexico S.A. de C.V., 2001a, p. 10-13).

In November, Asarco initiated a new mine plan at its Mission Mine Unit in Arizona. Under the plan, ore production was reduced from 56,000 t/d to 37,000 t/d, while total material mined was increased by 25%, thus increasing the stripping ratio and extending the reserve life at the mine from 14 to 22 years. The new plan was expected to boost average ore grades, increase recovery rates, and reduce unit production costs. Annual production of copper in concentrate was expected to decline by 22,000 t (ASARCO Inc., 2000b).

Montana Resources Inc. (49% owned by Asarco) suspended milling operations at its Continental Mine in Montana on June 30, citing "a dramatic escalation in power prices" as the reason for the shutdown. Stripping operations continued after the mill closed, and the company had anticipated resuming operations by yearend when it had expected utility rates to abate after the peak summer demand (Platt's Metal's Week, 2000b). At yearend, however, the mine remained closed and was not anticipated to reopen in the near term.

Despite numerous setbacks and limited interest by investment companies, Summo Minerals Corp. continued predevelopment work on its Lisbon Valley Copper Project, San Juan County, UT. The company resumed a drilling program early in the year in the Centennial SE Extension deposit and updated reserve calculations for a revised "final feasibility study," approved in September, for submission to banks for solicitation of financing. The plan design is for an open pit, heap-leach, SX-EW project producing 18,000 t/yr of cathode during a minimum 8.5-year period at anticipated cash and full operating costs of below $0.50 and $0.75 per pound of copper, respectively. Reserves were estimated at 333 Mt of ore grading an average 0.54% copper with a stripping ratio of 2.25 (Summo Minerals Corp., 2000a; 2000b).

At Kennecott Utah Copper Corp.'s Bingham Canyon Mine, production of copper increased by 5.9% to 296,000 t, and gold output rose 44% to 529,000 ounces compared with production in 1999. A 4% increase in ore milled, combined with a 4% and 44% increase, respectively, in copper and gold grades, accounted for the production growth. Copper ore grades had fallen from 0.62% copper in 1998 to 0.55% in 1999 and recovered, beginning midyear, to an annual average of 0.57% in 2000, still below the expected life-of-the-mine average. Kennecott anticipated that large-scale underground mining would extend mine life by 15 years when open pit reserves are exhausted around 2015. Refinery output increased nominally to 269,000 t with the smelter reportedly operating in excess of rated capacity (Rio Tinto plc, 2001, p. 37).

Nord Resources Corp. was seeking financing to return the Johnson Camp copper mine to full production. Nord acquired Johnson Camp in June 1999. In the first 6 months of 2000, the company incurred losses related to the planned redevelopment of the mine but operated on a close to break-even basis after that (Nord Resources Corp., 2000b). The Johnson Camp Copper Mine, 105 kilometers east of Tucson, AZ, is currently being operated on a maintenance basis. Since 1975, the mine has produced more than 68,000 t of cathode copper from open pit mining, heap leaching, and SX-EW processing of oxide ores. Although significant reserves remain, mining operations ceased in 1997. Heap leaching continues and the mine is producing 1 to 2 million pounds of copper annually. A detailed feasibility study to restart the Johnson Camp Mine demonstrated that the mine could produce 8,900 t per year of copper cathode for 11 years at an average cash cost of $0.63 per pound. Startup costs would total $13.5 million, including $7.9 million of capital investment and $5.6 million of working capital and other costs. Current reserves are placed at 3.2 Mt grading 0.417% copper (Nord Resources Corp., 2000a).

Consumption

Reported consumption of refined copper by domestic manufacturers continued its upward trend, rising by 1.6%, to 3.03 Mt. In addition to refined copper, domestic manufacturers directly consumed (melted or processed into chemicals) 1.3 Mt of copper-base scrap containing about 1 Mt of recoverable copper. An additional 75,000 t of copper was recovered in the consumption of aluminum-, nickel-, and zinc-base scrap.

Consumption of refined copper at wire-rod mills increased nominally and accounted for about 74% of domestic consumption of refined copper. For the third consecutive year, consumption growth at wire-rod mills was moderated by increased imports of wire rod, principally from Canada and Mexico, from which imports rose by 45,000 t to 225,000 t in 2000. Total imports rose by 63,000 t. Capacity utilization at domestic mills remained high following closure of two wire-rod mills in 1999. According to industry reports, despite increased imports, the U.S. wire-rod market was tight and at midyear experienced supply shortages. Wire-rod inventories in June fell to their lowest levels in recent years. An extended maintenance

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shut down at Grupo Minero Mexico S.A.'s Mexican wire-rod mill led to a 20% cutback in shipments in June, and production difficulties were also reported at Southwire Co., which had closed its secondary smelter and electrolytic refinery at the end of May (Platt's Metals Week, 2000d). In response to limited U.S. capacity and expectations of continued demand growth, Alcatel, a French-owned communications company with wire-rod mills in Canada, France, and Germany, announced plans to construct a 200,000-t/yr wire-rod mill in the southeastern United States. Commissioning was anticipated in 2 to 3 years (Platt's Metals Week, 2000a).

At brass mills, which were the second largest consumers of refined copper, consumption of refined copper rose by about 5%, while consumption of copper-base scrap rose by less than 2%, reflecting the continued impact of relatively low copper prices that reduced the cost of using refined copper and reduced the availability of scrap for processing. Brass mills still remained the largest consumers of scrap, accounting for about two-thirds of the total copper recoverable from scrap.

According to data compiled by the CDA (2001, p. 18), the supply of copper and copper-alloy products to the U.S. market by fabricators (wire mills, brass mills, foundries, and powder producers), including net imports, rose by about 4% to 4.3 Mt, up from the revised total of 4.16 Mt in 1999, and contained an estimated 3.9 Mt of copper. About 71% of these shipments was as unalloyed copper products. Wire mill products accounted for about 49% of total shipments to the domestic market; brass mill products, 47%; and foundry and powder products, 4%. In building construction, the largest end-use sector, shipments were essentially unchanged and accounted for about 39% of the market, down from 41% the previous year. Building construction included products used for building wire, plumbing and heating, air conditioning and commercial refrigeration, builders hardware, and architectural applications. Shipments for electric/electronic products and consumer/general products rose by 9% and 11%, respectively, and accounted for 28% and 11% of the market, respectively. Shipments for transportation equipment, 11%, and industrial machinery, 11%, rose slightly.

In May, Cerro Copper Products Co. announced that it had broken ground on a new "flagship" tube manufacturing and distribution center in Cedar City, UT. The tube mill was expected to be commissioned in 2001. The facility is part of a 3-year, $125 million expansion program. In addition to employing a unique, Cerro-developed process to produce both plumbing and air conditioning tube, the mill will be the only tube mill in the western United States (Cerro Copper Products, 2000). According to the Copper Development Association Inc. data (2001, p. 17), though down slightly in 2000, plumbing and commercial tube shipments to the U.S. market have risen 14% since 1995.

Prices and Stocks

Despite growing global inventories, copper prices in January continued the upward trend begun in mid-1999 and rose to their highest level in almost 2 years. The Commodity Exchange (COMEX) spot price averaged $0.85 per pound in January. With global inventories held on the commodity exchanges continuing to rise in February, prices began to weaken. Despite a sharp reversal in the upward trend in global inventories beginning in March, prices remained lower, the COMEX price averaging only $0.80 per pound in the March to June period. According to data compiled by the International Copper Study Group (2001a, p. 6), monthend inventories of refined copper on the global exchanges (LME, COMEX, and Shanghai Futures Exchange) peaked in February at 990,000 t before beginning a sustained slide that lasted through November when monthend inventories fell to 495,000 t. Prices began to respond to the decline in global stocks in May, and the average monthly COMEX price climbed to $0.91 per pound in September. Prices weakened and fluctuated during the fourth quarter of the year, the COMEX price averaging $0.86 per pound and finishing the year at $0.85 per pound. At yearend, inventories of copper held on the metals exchanges totaled 530,000 t, and total reported inventories, as reported by the International Copper Study Group (ICSG), decreased to 1.31 Mt, down from 1.62 Mt in 1999. At the prevailing rate of consumption, global inventories at yearend represented only about 31 days of supply, down from 41 days in 1999.

Trade

Net imports of refined copper rose sharply for the fifth consecutive year to 962,000 t, compared with 812,000 t in 1999. General imports of refined copper (1,025,000 t) were 30,000 t lower than imports for consumption as bonded material was removed from U.S.-located London Metal Exchange Ltd. (LME) warehouses. Beginning in March, LME inventories declined steadily and at yearend totaled 204,000 t, down from 412,000 t at yearend 1999. Exports of refined copper rose to 94,000 t, up from 25,000 t in 1999, and accounted for some of the drawdown in LME inventories.

Reduced domestic capacities led to shifts in the trade pattern for several copper products. Continuing the trend begun during the second half of 1999 following the closure of three primary smelters, the United States reverted to being a net exporter of copper in concentrates during 2000. The United States exported 175,000 t of copper in concentrate while having only negligible imports. Prior to 1998, the United States had been a long-term net exporter of concentrates. Reduced secondary processing capacity led to a surge in scrap exports; combined scrap exports of 486,000 t for 2000 exceeded exports of 315,000 t in 1999. China, including Hong Kong, was the largest recipient, accounting for 223,000 t, 46%, of total scrap exports. Owing to reduced capacity at domestic wire-rod mills, growth in industrial demand for wire rod was met by increased imports. Wire-rod imports (as reported by the U.S. Census Bureau and adjusted by the U.S. Geological Survey) rose to 247,000 t, up from 197,000 t in 1999 and 108,000 t in 1998.

According to U.S. Census Bureau data compiled by the Copper and Brass Fabricators Council Inc. (2001, p. 1-9), the United States imported 394,000 t of copper and copper-alloy semifabricated products, excluding wire-rod mill products, and exported 158,000 t. Net imports rose to 236,000 t, up from 139,000 t in 1999 and 86,000 t in 1998. Canada and Mexico accounted for 75% of semifabricated copper exports and 30% of imports.

Each year during the anniversary month of the publication of an antidumping or countervailing duty order, finding, or suspension of investigation, interested parties may request that the Department of Commerce conduct a review of the prevailing ruling. Numerous copper products for which antidumping or

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countervailing duties have been imposed were subject to review in 2000. In May, the International Trade Administration (ITA) ruled that revocation of antidumping duty orders against brass sheet and strip from the Republic of Korea, the Netherlands, and Sweden was not likely to lead to recurrence or continuation of material injury to the domestic industry and that it was revoking the duties effective January 1, 2000 (U.S. Department of Commerce, 2000b). Conversely, the ITA ruled to maintain antidumping and countervailing duty orders for brass sheet and strip from Brazil, Canada, France, Germany, Italy, and Japan (U.S. Department of Commerce, 2000a).

World Review

The global production oversupply for refined copper that developed at midyear 1997, and continued into 1999, began to shift during the first quarter of 2000. According to data compiled by the ICSG, reported world inventories of refined copper by the end of June had declined 220,000 t from those held at yearend 1999, and by yearend 2000 were down by 310,000 t to 1.3 Mt. At the prevailing rate of consumption, yearend world inventories represented a 31-day supply of refined copper, down from about 42 days at the end of 1999. Inventories held in LME warehouses declined by 433,000 t, overshadowing increases in reported consumer and Shanghai Futures Exchange inventories. The transition from production surplus in 1999 to production deficit in 2000 reflects a slowdown in refined production growth and an almost 8% growth in world refined copper consumption to 15.3 Mt. While consumption grew only about 2% in North America to 3.74 Mt, consumption by European Union countries grew by about 7% to 4.1 Mt, and Asian countries by about 11% to 6.1 Mt. Growth was particularly strong in China, where usage grew by about 25% to 1.88 Mt (International Copper Study Group, 2001a).

In 2000, despite the decline in U.S. capacity, estimated world mine capacity rose by 470,000 t/yr, or 3.4%, to 14.4 Mt/yr, extending the strong growth trend that began in 1995. Chile, Indonesia, and Kazakhstan accounted for most of the capacity expansion, their capacities having grown by 270,000 t/yr, 145,000 t/yr, and 90,000 t/yr, respectively. Capacity also increased significantly in Australia (33,000 t/yr) and China (30,000 t/yr). World smelter capacity, which had trended upward over the preceding 5 years, declined by about 150,000 t/yr. Indefinite closures of U.S. smelters were partially offset by expanded capacity in Australia (110,000 t/yr), where the Mount Isa smelter reached full capacity and the new Port Kembla smelter was commissioned during the year. In Korea, incremental expansions of the Onsan smelters boosted capacity by about 40,000 t/yr; in Bulgaria, expansion of the UM Pirdop smelter increased capacity by 45,000 t/yr; and in China, installation of an Isasmelt furnace at the Yunnan smelter boosted capacity by about 50,000 t (International Copper Study Group, 2001c, p.1-56). According to CRU International Ltd. (2001, p. 54-55), the supply of copper concentrates for smelting exceeded demand by about 230,000 t/yr of contained copper, and contract treatment (smelting) and refining charges assessed by smelters averaged about $0.18 per pound of recoverable copper, essentially unchanged from that in 1999.

World refinery capacity rose by about 140,000 t/yr, less than 1%, principally owing to expansion of electrowinning capacity in Chile. The decline in U.S. electrolytic refining capacity was offset by increased capacity in Australia, where the Port Kembla refinery was commissioned (60,000 t/yr expanding to 120,000 t/yr) and the Olympic Dam refinery was expanded by about 50,000 t/yr. In Indonesia, capacity increased by about 30,000 t/yr at the Gresik refinery, commissioned in 1999 (International Copper Study Group, 2000c, p. 57-98).

Outlook

U.S. mine production is expected to decline by about 100,000 t in 2001 as the full impact of 2000 mine plan changes is realized and new cost saving programs are implemented. Production is expected to decline by an additional 40,000 t in 2002. The Morenci Mine in Arizona already closed its remaining concentrator and converted to an all leach operation during the first quarter 2001, reducing its total output but increasing production of electrowon copper. At Miami, suspension of stripping in 2000 was expected to reduce output in 2001 and 2002 by 16,000 t and 38,000 t, respectively. The mine plan implemented by Asarco at its Mission Mine at yearend should further reduce production in 2001 by about 20,000 t. In June 2001, Kennecott announced that it would suspend operations from its higher cost North concentrator, reducing ore throughput by about 18% (Kennecott Utah Copper Corp., 2001). Following cutbacks in concentrate output, the three primary smelters closed in 1999 are expected to remain shuttered.

Primary refined production in 2001 is expected to decline only slightly owing to a decrease in net exports of concentrate and increased electrowon production. Secondary refined production is expected to fall following the May closure of Southwire Co.'s secondary smelter.

Domestic consumption of refined copper during the first 6 months of 2001 was down by about 10% from the same period in 2000. In addition to a more than 100,000 t decline in copper consumption at wire-rod mills, weakness in the wire-rod market was indicated by a 20,000-t decline in net imports of wire rod for the first 6 months of the year. Economic slowdown during the second half of 2001 was expected to keep demand at or below first half levels.

At the Annual General Session of the ICSG, held in June 2001, in Lisbon, Portugal, a consensus view of the world balance of copper supply and use for refined copper was developed by Government and industry delegates. According to the consensus, world production of refined copper from both primary and secondary sources in 2001 (adjusted to reflect primary feed shortages and disruptions to operations) is projected to increase by about 500,000 t (3.4%), while world refined copper use is expected to decline by about 100,000 t (less than 1%). This forecast follows a 10-year period of sustained demand growth. Consequently, the production deficit that developed in 2000 was expected to be reversed, and a small surplus of about 130,000 t of refined copper was anticipated. At the prevailing rate of use, this surplus represents only about a 3-day supply of copper. Projections by the ICSG for 2002 indicate that refined production, adjusted to reflect feed shortages and disruptions, will increase by only about 0.5% and will not keep pace with the projected 3.7% growth in demand. As a result, a production deficit is expected for 2002 (International Copper Study Group, 2001b).

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References Cited

ASARCO Inc., 2000a, Asarco to consolidate corporate functions in Arizona: New York, ASARCO Inc. news release, July 25, 1 p.

———2000b, Asarco Mission Mine plan: New York, ASARCO Inc. news release, October 30, 1 p.

Cerro Copper Products, 2000, Cerro selects flagship facility site: St. Louis, Cerro Copper Products news release, May 1, 2 p.

Copper and Brass Fabricators Council Inc., 2001, Import/export report: Washington DC, Copper and Brass Fabricators Council Inc., February, 62 p.

Copper Development Association Inc., 2001, Annual data 1999—Copper supply and consumption: New York, Copper Development Association Inc., 20 p.

CRU International Ltd., 2001, Copper quarterly industry and market outlook: London, CRU International Ltd., April, 72 p.

Grupo Mexico S.A. de C.V., 2001a, Annual report—2000: Mexico City, Grupo Mexico S.A. de C.V., 44 p.

———2001b, Grupo Mexico, S.A. de C.V. end of year 2000 results: Mexico City, Grupo Mexico S.A. de C.V. press release, February 28, 7 p.

International Copper Study Group, 2001a, Copper Bulletin: Lisbon, International Copper Study Group, v. 8, no. 8, 48 p.

———2001b, Copper forecast for 2001 and 2002: Lisbon, Portugal, International Copper Study Group press release, June 18, 1 p.

———2001c, Directory of copper mines and plants: Lisbon, International Copper Study Group, July, 89 p.

Kennecottt Utah Copper Corp., 2001, Kennecott to curtail operations: Magna, UT, Kennecott Utah Copper Corp. press release, May 25, 2 p.

Nord Resources Corp., 2000a, Nord Resources announces results of feasibility study on Johnson Camp: Albuquerque, Nord Resources Corp. press release, March 6, 2 p.

———2000b, Nord Resources announces third quarter 2000 results: Albuquerque, Nord Resources Corp. press release, December 19, 2 p.

Phelps Dodge Corp., 2000, Phelps Dodge expects second quarter and full-year 2000 results to be reduced by operational issues and restructuring charges: Phoenix, Phelps Dodge Corp. news release, June 27, 6 p.

———2001a, Form 10-K—2000: Securities and Exchange Commission, 124 p.

———2001b, Phelps Dodge reports 2000 earnings of 92 cents per share before nonrecurring charges: Phoenix, Phelps Dodge Corp. news release, January 25, 11 p.

Platt's Metals Week, 2000a, Alcatel plans new copper rod plant: Platt's Metals Week, v. 71, no. 32, August 7, p. 11.

———2000b, Montana's 10-mil lb/yr Continental moly mine closes: Platt's Metals Week, v. 71, no. 28, July 10, p. 1, 10.

———2000c, Phelps Dodge to invest $13 million in Sierrita copper mine: Platt's Metals Week, v. 71, no. 13, March 27, p. 13.

———2000d, U.S. rod tightens on production glitches; cathode firm: Platt's Metals Week, v. 71, no. 21, May 22, p. 10.

Rio Tinto plc, 2001, Annual report and accounts—2000: London, Rio Tinto plc, 136 p.

Southwire Co., 2000, Southwire to close copper refinery and sell aluminum smelter: Carrollton, GA, Southwire Co. news release, April 4, 2 p.

Summo Minerals Corp., 2000a, Increased ore reserves at Lisbon Valley copper project revised terms for fixed lump sum construction: Denver, Summo Minerals Corp. news release, October 3, 1 p.

———2000b, Lisbon Valley copper SX-EW project final bankable feasibility study completed: Denver, Summo Minerals Corp. news release, September 6, 2 p.

U.S. Department of Commerce, 2000a, Continuation of antidumping and countervailing duty orders for brass sheet and strip from Brazil, Canada, France, Italy, Germany, and Japan: Federal Register, May 1, p. 25304-25305.

———2000b, Revocation of antidumping duty orders—Brass sheet and strip from the Republic of Korea, the Netherlands, and Sweden: Federal Register, v. 65, no. 84, May 1, p. 25305.

U.S. Department of Labor, 2000, Superior-Essex, Pauline, KS—Notice of negative determination on reconsideration: Federal Register, v. 65, no. 87, May 4, p. 25948.

U.S. Environmental Protection Agency, 2000a, Copper sulfate pentahydrate; exemption from the requirement of a tolerance: Federal Register, v. 65, no. 221, November 15, p. 68908-68912.

———2000b, National emissions standards for hazardous air pollutants for source categories—National emissions standards for primary copper smelters: Federal Register, v. 65, no. 123, June 26, p. 39326-39334.

U.S. Geological Survey, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

U.S. Mint, 2001, The U.S. Mint reports to Congress on the success of the Golden Dollar coin after the first year: Washington, DC, U.S. Mint press release, April 2, 1 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Copper. Ch. in Metal Prices in the United States Through 1998, 1999.

Copper. Ch. in Mineral Commodity Summaries, annual.

Copper. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Copper. Mineral Industry Surveys, monthly.

The Nature and Use of Copper Reserve and Resource Data, Professional Paper 907-F, 1981.

Other

American Bureau of Metal Statistics (ABMS) Non-Ferrous Metal Data.

The Availability of Copper in Market Economy Countries, U.S. Bureau of Mines Information Circular 9310, 1992.

Copper. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Annual Data 2001—Copper Supply and Consumption: Copper Development Association Inc.

International Copper Study Group, monthly Copper Bulletin.

World Bureau of Metal Statistics (WBMS, London), monthly World Metals Statistics.

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TABLE 1
SALIENT COPPER STATISTICS 1/

(Metric tons unless otherwise specified)

		1996	1997	1998	1999	2000
United States:						
Mine production:						
Ore concentrated	thousand metric tons	274,000	284,000	268,000	236,000	202,000
Average yield of copper 2/	percent	0.47 r/	0.46	0.46	0.42 r/	0.44
Recoverable copper:						
Arizona		1,240,000	1,250,000	1,190,000	1,050,000	928,000
Michigan, Montana, Utah		339,000	337,000	337,000	313,000	W
New Mexico		256,000	259,000	252,000	197,000	195,000
Other States		85,600	96,500	78,900	37,400	321,000
Total		1,920,000	1,940,000	1,860,000	1,600,000	1,440,000
Total value	millions	$4,610	$4,570	$3,220	$2,680	$2,810
Smelter production:						
From domestic and foreign ores		1,300,000	1,440,000	1,490,000	1,090,000	(3/)
From scrap (new and old)		339,000	285,000	232,000	205,000	(3/)
Total		1,640,000	1,720,000	1,720,000	1,290,000	1,000,000
Byproduct sulfuric acid, sulfur content	thousand metric tons	1,240	1,430	1,420	1,130	830
Refinery production, primary materials:						
Electrolytic from domestic ores		1,290,000	1,370,000	1,290,000	1,110,000	865,000
Electrolytic from foreign materials		147,000	113,000	238,000	196,000	163,000
Electrowon		574,000	586,000	609,000	586,000	557,000
Total		2,010,000	2,070,000	2,140,000	1,890,000	1,590,000
Refinery production, secondary materials (scrap):						
Electrolytic		193,000	233,000	202,000	156,000	(3/)
Fire refined		152,000	163,000	147,000	73,700	(3/)
Total		345,000	396,000	349,000	230,000	208,000
Grand total		2,350,000	2,470,000	2,490,000	2,120,000	1,790,000
Secondary copper produced:						
Recovered from new scrap		891,000	967,000	956,000	949,000 r/	952,000
Recovered from old scrap		428,000	498,000	466,000	381,000	363,000
Total		1,320,000	1,460,000	1,420,000	1,330,000	1,310,000
Copper sulfate production		43,400	48,400	44,000 r/	52,700	55,500
Exports:						
Refined		169,000	92,900	86,200	25,200	93,600
Unmanufactured 4/		748,000	628,000	412,000	395,000	650,000
Imports:						
Refined		543,000	632,000	683,000	837,000	1,060,000
Unmanufactured 4/		961,000	999,000	1,190,000	1,280,000	1,350,000
Copper stocks, December 31:						
Blister and in-process material		173,000	180,000	160,000	138,000	122,000
Refined copper:						
Refineries		32,200	59,700	44,200	9,830	14,800
Wire rod mills		32,100	24,600	37,300	32,500 r/	28,600
Brass mills		14,000	14,300	20,800	23,800 r/	23,600
Other industry		2,700	3,390	3,870	3,870 r/	4,680
New York Commodity Exchange (COMEX)		26,600	83,000	85,200	83,100	58,700
London Metal Exchange (LME), U.S. warehouses		38,300	129,000	341,000	412,000	204,000
Total		146,000	314,000	532,000	565,000 r/	334,000
Consumption:						
Refined copper, reported		2,610,000	2,790,000	2,890,000	2,980,000 r/	3,030,000
Apparent consumption, primary refined and old scrap 5/		2,830,000	2,940,000 r/	3,030,000 r/	3,130,000	3,110,000
Price:						
Producer, weighted average	cents per pound	109.04	106.95	78.64	75.91	88.16
COMEX, first position	do.	105.87	103.58	75.08	72.11	83.97
LME, Grade A cash	do.	104.05	103.25	75.01	71.33	82.24
World, production:						
Mine	thousand metric tons	11,000	11,400	12,100 r/	12,700 r/	13,200 e/
Smelter	do.	10,800	11,200 r/	11,400	11,700 r/	11,900 e/
Refinery	do.	12,700	13,500	14,200 r/	14,600 r/	15,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

2/ Yield calculations are for concentrated ore only.

3/ Withheld to avoid disclosing company proprietary data; included in "Total."

4/ Includes copper content of alloy scrap.

5/ In 1998, 1999, and 2000, apparent consumption is calculated using General imports of 725,000 tons, 915,000 tons, and 1,020,000 tons respectively.

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TABLE 2
LEADING COPPER-PRODUCING MINES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT 1/

Rank	Mine	County and State	Operator	Source of copper	Capacity (thousand metric tons)
1	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper ore, concentrated and leached	450
2	Bingham Canyon	Salt Lake, UT	Kennecott Utah Copper Corp.	Copper-molybdenum ore, concentrated	310
3	Ray	Pinal, AZ	ASARCO Inc.	Copper ore, concentrated and leached	150
4	Chino	Grant, NM	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached	125
5	Bagdad	Yavapai, AZ	do.	do.	115
6	Sierrita	Pima, AZ	do.	do.	120
7	Mission Complex	do.	ASARCO Inc.	Copper ore, concentrated	110
8	Tyrone	Grant, NM	Burro Chief Copper Co.	Copper ore, leached	75
9	Miami (Inspiration)	Gila, AZ	Phelps Dodge Corp.	do.	75
10	Continental	Silver Bow, MT	Montana Resources Inc.	Copper-molybdenum ore, concentrated	50
11	Silver Bell	Pima, AZ	ASARCO Inc.	Copper ore, leached	21
12	San Manuel	Pinal, AZ	BHP Copper Co.	do.	25
13	Miami	Gila, AZ	do.	do.	12
14	Pinto Valley	do.	do.	do.	10

1/ The mines in this list accounted for 99% of the U.S. mine production in 2000.

TABLE 3
MINE PRODUCTION OF COPPER-BEARING ORES AND RECOVERABLE COPPER CONTENT OF ORES PRODUCED IN THE UNITED STATES, BY SOURCE AND TREATMENT PROCESS 1/

(Metric tons)

	1999		2000	
Source and treatment process	Gross weight	Recoverable copper	Gross weight	Recoverable copper
Mined copper ore:				
Concentrated	236,000,000	1,000,000	202,000,000 2/	879,000
Leached	NA	586,000	NA	557,000
Total	NA	1,590,000	NA	1,440,000
Copper precipitates shipped: leached from tailings, dumps, and in-place material	7,850 r/	6,230	3,910	2,810
Other copper-bearing ores 3/	6,550,000	7,220	9,880,000	5,310
Grand total	XX	1,600,000	XX	1,440,000

r/ Revised. NA Not available. XX Not applicable.
1/ Data rounded to three significant digits; may not add to totals shown.
2/ In 2000, 17,243 kilograms of gold and 285 metric tons of silver were recovered from concentrated ore. The average value of gold and silver per metric ton of ore concentrated was $0.72.
3/ Includes gold ore, lead ore, silver ore, silver-copper ore, zinc ore, and ore shipped directly to smelter.

TABLE 4
CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM 1/

(Metric tons)

Item	Brass mills	Wire rod mills	Foundries, chemical plants, miscellaneous users	Smelters, refiners, ingot makers	Total
1999:					
Copper scrap	1,010,000 r/	W	79,900	535,000 r/ 2/	1,630,000
Refined copper 3/	691,000	2,230,000	52,200 r/	4,480	2,980,000 r/
Hardeners and master alloys	703	--	2,100	--	2,800
Brass ingots	--	--	124,000 r/	--	124,000 r/
Slab zinc	55,800	--	(4/)	(4/)	78,200 r/
2000:					
Copper scrap	1,030,000	W	83,000	482,000 2/	1,600,000
Refined copper 3/	723,000	2,240,000	59,800	4,590	3,030,000
Hardeners and master alloys	621	--	2,260	--	2,880
Brass ingots	--	--	122,000	--	122,000
Slab zinc	57,500	--	(4/)	(4/)	82,800

See footnotes at end of table.

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TABLE 4--Continued
CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM 1/

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Smelters, refiners, ingot makers." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes item indicated by symbol W.
3/ Detailed information on consumption of refined copper can be found in table 5.
4/ Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 5
CONSUMPTION OF REFINED COPPER SHAPES IN THE UNITED STATES, BY CLASS OF CONSUMER 1/

(Metric tons)

Class of consumer	Cathodes	Ingots and ingot bars	Cakes and slabs	Wirebar, billets, other	Total
1999:					
Wire rod mills	2,220,000	--	--	16,800	2,230,000
Brass mills	492,000	18,300	79,300	102,000	691,000
Chemical plants	--	--	--	1,220	1,220
Ingot makers	W	W	W	4,480 2/	4,480
Foundries	3,460	6,100 r/	--	11,600	21,200 r/
Miscellaneous 3/	W	W	W	29,800 2/	29,800
Total	2,710,000	24,400 r/	79,300	166,000	2,980,000 r/
2000:					
Wire rod mills	2,220,000	--	--	18,700	2,240,000
Brass mills	501,000	18,300	101,000	103,000	723,000
Chemical plants	--	--	--	1,200	1,200
Ingot makers	W	W	W	4,590 2/	4,590
Foundries	3,810	5,530	--	16,700	26,000
Miscellaneous 3/	W	W	W	32,600 2/	32,600
Total	2,730,000	23,800	101,000	176,000	3,030,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Wirebar, billets, other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes items indicated by symbol W.
3/ Includes consumers of copper powder and copper shot, iron and steel plants, primary smelters producing alloys other than copper, and other manufacturers.

TABLE 6
COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
Kind of scrap:		
New scrap:		
Copper-base	903,000	906,000
Aluminum-base	46,200 r/	45,500
Nickel-base	94	18
Total	949,000 r/	952,000
Old scrap:		
Copper-base	349,000	334,000
Aluminum-base	31,200 r/	28,400
Nickel-base	44	170
Zinc-base	31	32
Total	381,000	363,000
Grand total	1,330,000	1,310,000
Form of recovery:		
As unalloyed copper:		
At electrolytic plants	156,000	128,000
At other plants	81,800	88,400
Total	238,000	217,000
In brass and bronze	1,000,000	1,010,000
In alloy iron and steel	599 r/	549
In aluminum alloys	78,200 r/	74,900

See footnotes at end of table.

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TABLE 6--Continued
COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
Form of recovery--Continued:		
In chemical compounds	11,800 2/	11,700
Total	1,090,000	1,100,000
Grand total	1,330,000	1,310,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ 1999 data reflects expanded coverage to include copper sulfate and other copper chemical producers.

TABLE 7
COPPER RECOVERED AS REFINED COPPER AND IN ALLOYS AND OTHER FORMS
FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF OPERATION 1/

(Metric tons)

	From new scrap		From old scrap		Total	
Type of operation	1999	2000	1999	2000	1999	2000
Ingot makers	34,700	29,900	94,700	90,700	129,000	121,000
Refineries 2/	48,800	39,000	181,000	169,000	230,000	208,000
Brass and wire rod mills	804,000	822,000	25,900	22,200	830,000	844,000
Foundries and manufacturers	11,400	10,800	40,000	44,500	51,400	55,400
Chemical plants 3/	3,940	3,880	7,840	7,840	11,800	11,700
Total	903,000	906,000	349,000	334,000	1,250,000	1,240,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Electrolytically refined and fire-refined scrap based on source of material at smelter level.
3/ 1999 data reflects expanded coverage to include copper sulfate and other copper chemical producers.

TABLE 8
PRODUCTION OF SECONDARY COPPER AND COPPER-ALLOY PRODUCTS
IN THE UNITED STATES, BY ITEM PRODUCED FROM SCRAP 1/

(Metric tons)

Item produced from scrap	1999	2000
Unalloyed copper products:		
Electrolytically refined copper	156,000	128,000
Fire-refined copper	73,700	80,000
Copper powder	7,420	7,510
Copper castings	647	839
Total	238,000	217,000
Alloyed copper products:		
Brass and bronze ingots:		
Tin bronzes	15,800 r/	14,600
Leaded red brass and semired brass	97,300 r/	93,500
High leaded tin bronze	13,000	12,700
Yellow brass	6,010	5,650
Manganese bronze	7,060 r/	6,240
Aluminum bronze	6,870	7,030
Nickel silver	2,050	2,260
Silicon bronze and brass	4,530	4,680
Copper-base hardeners and master alloys	13,200 r/	13,800
Miscellaneous	169 r/	3,500
Total	166,000 r/	164,000
Brass mill and wire-rod mill products	1,030,000	1,060,000
Brass and bronze castings	43,400	45,600
Brass powder	214	198
Copper in chemical products	11,800 2/	11,700
Grand total	1,490,000 r/	1,490,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ 1999 data reflects expanded coverage to include copper sulfate and other copper chemical products.

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TABLE 9
COMPOSITION OF SECONDARY COPPER-ALLOY PRODUCTION IN THE UNITED STATES 1/

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production: 2/							
1999 r/	137,000	4,850	7,900	15,700	267	19	166,000
2000	136,000	5,240	8,430	14,400	252	14	164,000
Secondary metal content of brass mill products:							
1999	830,000	950	7,840	188,000	W	W	1,030,000
2000	844,000	1,650	7,450	199,000	W	W	1,060,000
Secondary metal content of brass and bronze castings:							
1999	39,100	708	1,100	2,260	112	119	43,400
2000	42,200	633	837	1,700	85	98	45,600

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes about 97% from scrap and 3% from other than scrap in 1999 (revised) and about 96% from scrap and 4% from other than scrap in 2000.

TABLE 10
CONSUMPTION AND YEAREND STOCKS OF COPPER-BASE SCRAP 1/

(Metric tons, gross weight)

	1999		2000	
Scrap type and processor	Consumption	Stocks	Consumption	Stocks
No. 1 wire and heavy:				
Smelters, refiners, ingot makers	106,000	2,360 r/	86,000	2,260
Brass and wire-rod mills	431,000	(2/)	438,000	(2/)
Foundries and miscellaneous manufacturers	41,200	2,520	45,500	2,650
No. 2 mixed heavy and light:				
Smelters, refiners, ingot makers	137,000	6,020 r/	133,000	2,120
Brass and wire-rod mills	21,200	(2/)	13,800	(2/)
Foundries and miscellaneous manufacturers	3,230	226	3,320	193
Total unalloyed scrap:				
Smelters, refiners, ingot makers	243,000	8,380 r/	219,000	4,370
Brass and wire-rod mills	452,000	20,300	452,000	17,600
Foundries and miscellaneous manufacturers	44,500	2,740 r/	48,800	2,840
Red brass: 3/				
Smelters, refiners, ingot makers	50,200	2,150 r/	52,700	2,120
Brass mills	10,400	(2/)	9,330	(2/)
Foundries and miscellaneous manufacturers	10,600	(2/)	12,400	(2/)
Leaded yellow brass:				
Smelters, refiners, ingot makers	20,600	1,110 r/	16,500	1,210
Brass mills	400,000	(2/)	396,000	(2/)
Foundries and miscellaneous manufacturers	1,740	(2/)	1,680	(2/)
Yellow and low brass, all plants	76,600	1,160 r/	105,000	713
Cartridge cases and brass, all plants	79,400	(2/)	72,600	(2/)
Auto radiators:				
Smelters, refiners, ingot makers	53,400	2,130 r/	48,300	1,610
Foundries and miscellaneous manufacturers	4,650	(2/)	2,750	(2/)
Bronzes:				
Smelters, refiners ingot makers	16,100	886 r/	11,100	1,130
Brass mills and miscellaneous manufacturers	10,600	(2/)	11,800	(2/)
Nickel-copper alloys, all plants	23,000	369 r/	28,100	314
Low grade and residues:				
Smelters, refiners, miscellaneous manufacturers	111,000	13,100 r/	88,600	7,670
Other alloy scrap: 4/				
Smelters, refiners, ingot makers	12,100	839 r/	11,300	324
Brass mills and miscellaneous manufacturers	6,740	(2/)	7,600	(2/)
Total alloyed scrap:				
Smelters, refiners, ingot makers	258,000	21,200 r/	221,000	15,300
Brass mills	593,000	35,500	620,000	39,500
Foundries and miscellaneous manufacturers	35,500	3,030 r/	34,200	2,360
Total scrap:				
Smelters, refiners, ingot makers	501,000	29,600 r/	440,000	19,600
Brass and wire-rod mills	1,050,000	55,700	1,070,000	57,200
Foundries and miscellaneous manufacturers	79,900	5,770 r/	83,000	5,210

See footnotes at end of table.

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TABLE 10--Continued
CONSUMPTION AND YEAREND STOCKS OF COPPER-BASE SCRAP 1/

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Individual breakdown is not available; included in "Total unalloyed scrap," "Total alloyed scrap," and "Total scrap."
3/ Includes cocks and faucets, commercial bronze, composition turnings, gilding metal, railroad car boxes, and silicon bronze.
4/ Includes aluminum bronze, beryllium copper, and refinery brass.

TABLE 11
CONSUMPTION OF PURCHASED COPPER-BASE SCRAP 1/ 2/

(Metric tons, gross weight)

Type of operation	From new scrap		From old scrap		Total	
	1999	2000	1999	2000	1999	2000
Ingot makers	46,300	44,000	132,000	125,000	178,000	169,000
Smelters and refineries	71,100	58,800	252,000	212,000	323,000	271,000
Brass and wire-rod mills	1,020,000	1,050,000	26,800	23,000	1,050,000	1,070,000
Foundries and miscellaneous manufacturers	27,200	26,200	52,700	56,800	79,900	83,000
Total	1,160,000	1,180,000	464,000	417,000	1,630,000	1,600,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Consumption at brass and wire-rod mills assumed equal to receipts.

TABLE 12
FOUNDRIES AND MISCELLANEOUS MANUFACTURERS
CONSUMPTION OF BRASS INGOT, REFINED COPPER AND
COPPER SCRAP IN THE UNITED STATES 1/

(Metric tons)

Ingot type or material consumed	1999	2000
Tin bronzes	33,200	29,900
Leaded red brass and semired brass	70,100 r/	71,000
Yellow, leaded, low brass 2/	8,520 r/	8,510
Manganese bronze	4,720	4,590
Nickel silver 3/	2,710	3,480
Aluminum bronze	4,140	4,650
Hardeners and master alloys 4/	2,100	2,260
Lead free alloys 5/	141 r/	145
Total brass ingot	126,000 r/	125,000
Refined copper	52,200 r/	59,800
Copper scrap	79,900	83,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes brass and silicon bronze.
3/ Includes brass, copper nickel, and nickel bronze.
4/ Includes special alloys.
5/ Includes copper-bismuth and copper-bismuth-selenium alloys.

TABLE 13
AVERAGE PRICES FOR COPPER SCRAP AND ALLOY-INGOT, BY TYPE

(Cents per pound)

Year	Brass mills No. 1 scrap	Refiners No. 2 scrap	Dealers' buying (New York) No. 2 scrap	Dealers' buying (New York) Red brass turnings and borings	Alloy-ingot (New York) 1/ No. 115 brass (85-5-5-5)	Alloy-ingot (New York) 1/ Yellow brass (405)
1999	70.88	57.53	42.97	37.74	138.50	135.25
2000	80.67	64.99	51.43	39.95	138.50	135.25

1/ List price quotes effective July 1996.

Source: American Metal Market.

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TABLE 14
U.S. EXPORTS OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY 1/

Country	Ore and concentrate		Matte, ash, precipitates		Refined		Unalloyed copper scrap		Blister and anodes		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999	63,100 r/	$72,500 r/	26,700	$34,700	25,200	$42,100	128,000	$166,000	30,800	$54,400	274,000	$369,000
2000:												
Belgium	--	--	48	78	--	--	731	5,320	397	532	1,180	5,930
Brazil	3,090	5,270	3	9	15	22	97	106	33	68	3,240	5,480
Canada	45,000	68,500	13,100	10,500	5,990	12,000	45,300	50,900	10,400	13,300	120,000	155,000
China	8,500	11,000	10	95	52,700	99,400	124,000	101,000	61	120	185,000	212,000
Finland	4,680	7,990	--	--	19	47	--	--	--	--	4,690	8,030
Germany	6,100	10,200	--	--	123	281	2,070	5,270	383	758	8,670	16,500
Hong Kong	111	135	3	4	1,750	3,310	6,900	6,870	2,330	5,320	11,100	15,600
Italy	7	25	5	7	97	145	147	463	510	1,100	766	1,740
Japan	483	1,290	56	551	74	110	15,900	38,900	1,990	4,680	18,500	45,500
Korea, Republic of	1,180	8,080	10	24	538	880	20,600	31,500	589	1,380	22,900	41,900
Mexico	31,500	22,900	17,900	22,500	2,980	5,460	2,760	7,350	1,680	2,650	56,800	60,900
Philippines	4,300	6,920	--	--	4	6	28	31	89	261	4,420	7,220
Singapore	115	297	--	--	7,220	14,600	979	1,050	953	2,280	9,270	18,300
Taiwan	65	79	93	315	20,400	36,700	5,080	7,530	2,230	5,180	27,900	49,900
United Kingdom	600	673	40	88	33	50	113	253	439	976	1,230	2,040
Other	1,200	2,530	90	223	1,640	3,190	2,840	3,530	1,250	2,930	7,020	12,400
Total	107,000	146,000	31,300	34,300	93,600	176,000	228,000	260,000	23,300	41,600	483,000	658,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 15
U.S EXPORTS OF COPPER SEMIMANUFACTURES, BY COUNTRY 1/

Country	Pipes and tubing		Plates, sheets, foil, bars		Bare wire, including wire rod 2/		Wire and cable, stranded		Copper sulfate	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999	26,100	$78,900	42,200	$159,000	46,300	$118,000	25,000	$94,500	10,600 r/	$23,000 r/
2000:										
Australia	23	121	4	90	5	41	76	1,090	261	643
Belgium	178	1,120	33	197	45	188	109	1,220	--	--
Brazil	26	162	12	227	78	2,260	1,700	12,200	76	216
Canada	9,920	31,200	24,700	89,400	16,700	42,200	4,190	12,900	777	1,590
China	215	656	1,360	3,680	21	285	504	937	833	1,840
Colombia	103	390	12	50	7	42	486	2,640	--	--
Denmark	44	234	18	86	11	89	22	280	382	917
Dominican Republic	27	55	22	71	1,280	3,010	238	776	--	--
France	811	4,320	90	939	69	990	119	3,090	90	210
Germany	19	105	1,400	7,130	65	1,170	209	9,420	31	142
Hong Kong	61	106	1,010	5,010	341	2,960	207	1,510	325	633
India	313	1,120	26	284	1	17	45	322	--	--
Indonesia	--	--	--	--	--	--	14	84	179	433
Israel	305	945	17	658	31	518	86	531	--	--
Italy	2,390	7,130	98	579	2	28	28	599	183	486
Japan	22	119	5,470	10,000	82	530	184	2,060	826	1,990
Korea, Republic of	187	915	1,330	6,210	27	260	261	2,870	2,060	4,540
Mexico	11,800	32,700	3,740	14,400	53,000	143,000	17,800	77,700	59	195
Netherlands	447	2,510	43	284	4	81	14	228	19	44
Philippines	31	103	239	1,720	--	--	28	251	15	47
Saudi Arabia	249	849	51	100	39	183	842	2,290	--	--
Singapore	12	54	179	886	145	878	568	3,420	236	560
Spain	112	369	11	169	9	86	31	273	125	332
Sweden	--	--	9	405	8	117	27	664	1,650	4,370
Taiwan	53	244	1,200	5,460	244	967	41	519	611	1,450
United Kingdom	290	1,550	328	3,440	97	658	166	2,570	1,120	2,830
Venezuela	87	293	6	41	343	828	478	2,220	62	780
Other	1,080	3,430	1,010	5,690	2,230	7,240	2,920	14,400	364	892
Total	28,800	90,800	42,400	157,000	74,900	208,000	31,400	157,000	10,300	25,100

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Total exports of wire rod in 1999 were 28,400 tons valued at $58,800,000 and in 2000 were 44,100 tons valued at $98,000,000.

Source: U.S. Census Bureau.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY 1/

Country	Ore and concentrate		Matte, ash, precipitates		Blister and anode		Refined		Unalloyed scrap		Total	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
1999	143,000	$83,700	1,730	$1,580	193,000	$461,000	837,000	$1,360,000	34,400	$45,600	1,210,000	$1,950,000
2000:												
Brazil	--	--	--	--	--	--	2,510	3,650	--	--	2,510	3,650
Bulgaria	--	--	--	--	4,040	10,300	56	105	--	--	4,100	10,400
Canada	--	--	20	62	53,500	158,000	268,000	512,000	9,130	14,500	330,000	685,000
Chile	--	--	1	16	76,200	143,000	258,000	453,000	275	476	334,000	596,000
China	--	--	2	4	--	--	1,410	2,450	--	--	1,410	2,450
Costa Rica	--	--	--	--	--	--	--	--	947	1,050	947	1,050
Dominican Republic	--	--	--	--	--	--	--	--	1,480	1,780	1,480	1,780
Finland	--	--	--	--	2,180	4,570	178	471	--	--	2,360	5,050
Germany	--	--	(3/)	3	18	44	3,700	8,260	283	345	4,000	8,650
Guatemala	--	--	--	--	--	--	--	--	536	624	536	624
Honduras	--	--	--	--	--	--	--	--	402	492	402	492
Italy	--	--	--	--	2,180	4,100	(3/)	6	251	1,590	2,430	5,690
Japan	--	--	--	--	--	--	5,010	11,700	124	879	5,130	12,600
Kazakhstan	--	--	--	--	--	--	54,900	101,000	--	--	54,900	101,000
Mexico	--	--	757	453	19,500	62,900	80,400	149,000	15,100	18,400	116,000	230,000
Namibia	--	--	--	--	2,750	5,880	--	--	--	--	2,750	5,880
Peru	--	--	--	--	5,960	11,200	311,000	580,000	277	609	317,000	592,000
Poland	--	--	--	--	--	--	10,200	20,100	--	--	10,200	20,100
Russia	--	--	--	--	117	203	58,900	115,000	1	14	59,000	115,000
Spain	--	--	--	--	5,670	11,100	--	--	--	--	5,670	11,100
Turkey	--	--	--	--	11,000	20,300	1,100	1,780	--	--	12,000	22,100
Venezuela	--	--	--	--	--	--	--	--	418	462	418	462
Other	53	12	903	2,240	1,680	3,030	1,050	2,110	1,590	2,120	5,220	7,250
Total	53	12	1,680	2,780	185,000	435,000	1,060,000	1,960,000	30,900	43,400	1,270,000	2,440,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value at U.S. port.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 17
U.S. IMPORTS FOR CONSUMPTION OF COPPER SEMIMANUFACTURES, BY COUNTRY 1/

Country	Pipes and tubing		Plates, sheets, foil, bars		Bare wire, including wire rod 2/		Wire and cable, stranded		Copper sulfate	
	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)
1999	434	$2,280	79,500 r/	$257,000 r/	197,000 r/	$354,000 r/	9,430	$37,700	26,700	$21,200
2000:										
Australia	(4/)	9	67	135	--	--	--	--	300	4,890
Belgium	--	--	1,200	3,370	217	920	--	--	--	--
Brazil	--	--	2,040	4,550	13,300	36,200	1	5	--	--
Canada	368	2,120	14,700	46,300	116,000	240,000	1,050	3,210	--	--
Chile	2	7	4,850	12,100	501	1,040	--	--	--	--
Costa Rica	--	--	--	--	72	175	592	1,480	--	--
Finland	3	15	4,020	14,200	549	2,100	4	28	--	--
France	--	--	2,980	7,820	586	5,730	119	1,070	254	653
Germany	5	48	26,100	78,100	663	3,540	381	2,510	304	688
Hong Kong	--	--	9	80	3	6	5	54	288	358
India	6	43	176	187	(4/)	2	38	1,180	--	--
Israel	--	--	--	--	946	3,980	2,740	16,400	--	--
Italy	--	--	6,600	17,100	6	54	--	--	--	--
Japan	5	293	12,900	56,100	1,630	8,110	69	922	8	105
Korea, Republic of	14	29	2,040	4,480	7,980	26,900	12	87	54	85
Luxembourg	--	--	3,440	24,300	--	--	--	--	--	--
Malaysia	278	937	1,060	7,100	3	46	--	--	--	--
Mexico	(4/)	11	18,900	38,800	110,000	204,000	(4/)	13	1,290	2,970
Norway	--	--	(4/)	13	--	--	--	--	54	115
Peru	--	--	2,270	5,580	231	537	69	142	--	--
Poland	--	--	38	67	9	60	628	1,820	--	--
Sweden	--	--	11,500	38,800	15	97	--	--	--	--
Turkey	--	--	125	309	6,090	20,100	1,780	6,400	--	--
United Kingdom	4	87	2,000	8,650	3,200	7,200	32	189	2	46
Other	334	1,150	3,120	12,400	3,440	9,060	109	614	--	--
Total	1,020	4,750	120,000	381,000	266,000	570,000	7,620	36,100	2,550	9,910

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Total imports of wire rod in 1999 were 193,000 tons valued at $330,000,000 and in 2000 were 247,000 tons valued at $502,000,000. Imports data adjusted by USGS to correct misclassification of imports from Mexico.

3/ C.i.f. value at U.S. port.

4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 18
U.S. EXPORTS OF COPPER SCRAP, BY COUNTRY 1/

	Unalloyed copper scrap				Copper-alloy scrap			
	1999		2000		1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	1,540	$13,500	731	$5,320	361	$1,160	1,280	$1,730
Canada	31,800	32,900	45,300	50,900	35,700	42,300	41,400	56,700
China	51,300	47,400	124,000	101,000	34,800	26,400	86,100	65,700
Germany	1,120	3,950	2,070	5,270	2,120	3,520	5,610	9,920
Hong Kong	9,390	10,700	6,900	6,870	4,040	4,720	6,240	6,700
India	2,580	2,430	933	963	26,100	24,100	24,000	19,400
Japan	10,500	28,300	15,900	38,900	9,690	13,200	16,200	24,700
Korea, Republic of	7,630	12,100	20,600	31,500	34,800	41,100	39,700	54,800
Mexico	1,610	2,310	2,760	7,350	20,700	19,400	14,700	14,600
Singapore	1,960	1,900	979	1,050	213	219	2,440	2,920
Spain	2,760	526	589	272	2,670	1,610	5,460	1,400
Taiwan	4,120	6,590	5,080	7,530	7,510	10,100	6,190	7,620
United Arab Emirates	203	221	28	31	1,400	2,340	266	316
United Kingdom	555	1,060	113	253	1,700	2,370	713	553
Other	1,250 r/	1,940 r/	1,560	2,860	5,040 r/	7,590 r/	7,480	9,400
Total	128,000	166,000	228,000	260,000	187,000	200,000	258,000	276,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 19
U.S. IMPORTS FOR CONSUMPTION OF COPPER SCRAP, BY COUNTRY 1/

	Unalloyed copper scrap		Copper-alloy scrap		
Country or territory	Quantity (metric tons)	Value 2/ (thousands)	Gross weight (metric tons)	Copper content e/ 3/ (metric tons)	Value 2/ (thousands)
1999	34,400	$45,600	102,000	73,300	$122,000 r/
2000:					
Canada	9,130	14,500	54,400	39,200	72,100
Chile	275	476	958	690	1,530
Colombia	146	165	2,670	1,920	4,060
Costa Rica	947	1,050	876	630	999
Dominican Republic	1,480	1,780	1,530	1,100	1,620
Guatemala	536	624	1,730	1,250	2,680
Honduras	402	492	776	559	628
Italy	251	1,590	--	--	--
Jamaica	278	465	936	674	738
Japan	124	879	37	27	69
Malaysia	--	--	827	596	1,650
Mexico	15,100	18,400	29,400	21,200	32,400
Spain	--	--	4,100	2,950	2,930
Taiwan	17	22	1,150	829	1,460
United Kingdom	11	32	2,550	1,840	4,340
Venezuela	418	462	1,760	1,270	1,640
Other	1,700	2,400	9,140	6,580	13,700
Total	30,900	43,400	113,000	81,200	143,000

e/ Estimated. r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value at U.S. port.
3/ Content is estimated by USGS to be 72% of gross weight.

Source: U.S. Census Bureau.

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TABLE 20
COPPER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Albania e/	2,500	220	3,200	900	900
Argentina	-- e/	30,421	170,273	210,126 r/	145,197 3/
Armenia e/	9,100	9,000	9,200	9,600	7,231 3/
Australia:					
By concentration or cementation	503,100	507,400	552,000	655,900 r/	751,300
Leaching (electrowon)	44,200	50,600	55,000	83,100	77,700
Total	547,300	558,000	607,000	739,000 r/	829,000 3/
Bolivia	92	182	48	252 r/	110 3/
Botswana 4/	25,275	22,840	25,043	37,604 r/	38,420 3/
Brazil (concentrate)	46,203	39,952	34,446 r/	31,371 r/	31,786 3/
Bulgaria	89,000	93,000	88,000	76,000 r/	75,000
Burma:					
By concentration or cementation	4,841	2,927	--	97 r/	100
Leaching (electrowon)	--	--	6,700 e/	26,736	26,711 3/
Total	4,841	2,927	6,700 e/	26,833	26,811 3/
Canada:					
By concentration or cementation	685,900	656,800	703,966	620,085 r/	634,162 3/
Leaching (electrowon)	2,500	2,700	1,800	--	-- 3/
Total	688,400	659,500	705,766	620,085 r/	634,162 3/
Chile: 5/					
By concentration or cementation	2,480,100	2,511,000	2,578,800	3,029,100 r/	3,229,800 3/
Leaching (electrowon)	635,700	881,000	1,108,000	1,362,100 r/	1,372,600 3/
Total	3,115,800	3,392,000	3,686,800	4,391,200 r/	4,602,400 3/
China e/	439,000	496,000	486,000	520,000 r/	590,000
Colombia e/	2,222 3/	1,800	1,400	1,400	1,400
Congo (Kinshasa): 6/					
By concentration or cementation e/	6,200	--	--	--	--
Leaching (electrowon)	43,800	39,651 r/	34,994 r/	32,000 r/ e/	21,000
Total	50,000 e/	39,651 r/	34,994 r/	32,000 r/ e/	21,000
Cuba e/	2,000	1,000	1,000	1,000	1,000
Cyprus: Leaching (electrowon)	1,688	3,900	7,800	11,300 r/ e/	11,300
Ecuador e/	100	100	100	100	100
Finland e/	9,261 3/	8,500	9,000	10,500 r/	11,600 3/
Georgia	5,100	4,100	6,000 e/	8,000	8,000
Honduras	(7/)	(7/)	(7/)	(7/)	--
India	47,800	37,200 e/	39,900	34,100 r/ e/	35,500 3/
Indonesia 6/	507,484	529,121	780,780	766,027 r/	1,012,054 3/
Iran: e/					
By concentration or cementation	108,000 r/	108,000 r/	128,300 r/ 3/	131,000 r/ 3/	131,000
Leaching (electrowon)	1,500 r/	9,500 r/	14,000 r/	14,000	14,000
Total	109,000 r/	118,000 r/	142,000 r/	145,000 r/	145,000
Japan	1,145	932	1,070	1,038	1,211 3/
Kazakhstan	250,000 e/	316,166	337,600	374,000 e/	430,000
Korea, North e/	16,000	16,000	14,000	14,000	14,000
Korea, Republic of	3	-- e/	41	--	-- 3/
Macedonia	8,484	13,000	9,100	10,200 r/	10,000
Malaysia	20,219	18,821	13,907	4,600 r/	-- 3/
Mexico:					
By concentration or cementation	295,303	342,319	335,822	330,232 r/	319,766 3/
Leaching (electrowon)	45,407	48,217	48,819	50,952	44,800 3/
Total	340,710	390,536	384,641	381,184 r/	364,566 3/
Mongolia	123,039	124,400	125,400	126,700	124,800 3/
Morocco	14,600 r/	15,400	8,200 r/	7,700 r/	7,100 3/
Namibia	14,845	17,879	6,500	--	5,070
Norway	7,400	6,671	2,698 r/ 3/	-- e/	--
Papua New Guinea	186,665 r/	111,515 r/	152,200 r/	187,921 r/	200,900 3/
Peru:					
By concentration or cementation	396,060	406,760	381,501	421,470 r/	426,614 3/
Leaching (electrowon)	88,171	99,738	101,837	114,917	127,310 3/
Total	484,231	506,498	483,338	536,387 r/	553,924 3/
Philippines	61,600	48,600 r/	45,400 r/	37,600 r/	32,000
Poland	421,900	414,800	436,200	464,000 r/	456,200 3/
Portugal	109,935	106,479	114,637	99,500 e/	76,200

See footnotes at end of table.

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TABLE 20--Continued
COPPER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Romania 8/	24,434	23,190	19,065 r/	16,455 r/	16,079 3/
Russia	523,000	505,000 e/	500,000	530,000 e/	570,000
Saudi Arabia	834	703	782 r/	821 r/	830
Serbia and Montenegro	69,500	73,600	70,900	51,700	41,000
Slovakia e/	386	314	155 r/	124 r/	--
South Africa	152,595	153,058	166,000	144,263	137,092 3/
Spain	37,510	37,883	37,000	1,740 r/	23,300 3/
Sweden	71,660	86,640	73,685 r/	71,200 r/	75,600 3/
Turkey 8/	33,792 r/	36,400 r/	40,000 r/ e/	73,051 r/	76,253 3/
United States: 6/					
By concentration or cementation	1,350,000	1,350,000	1,250,000	1,010,000 r/	887,000 3/
Leaching (electrowon)	574,000	586,000	609,000	586,000	557,000 3/
Total	1,920,000	1,940,000	1,860,000	1,600,000	1,440,000 3/
Uzbekistan	65,000 e/	73,000	65,000	60,000 e/	65,000
Zambia: 9/					
By concentration or cementation (smelted)	276,000	288,900	258,000	213,000 r/	186,200 3/
Leaching (electrowon)	58,000 e/	64,000	57,000	57,000 e/	55,000 3/
Total	334,000	352,900	315,000	270,000 r/ e/	241,200 3/
Zimbabwe: e/					
By concentration or cementation	6,000 r/	3,900	3,600	3,491 r/ 3/	2,104 3/
Leaching (electrowon)	3,200	2,900	2,400	1,020 r/ 3/	--
Total	9,200 r/	6,800	6,000	4,511 r/ 3/	2,104 3/
Grand total	11,000,000	11,400,000	12,100,000 r/	12,700,000 r/	13,200,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Data represent copper content by analysis of concentrates produced except where otherwise noted. Table includes data available through July 20, 2001.

3/ Reported figure.

4/ Copper content of pelletized nickel-copper matte produced in smelter.

5/ Reported by Comision Chilena del Cobre. Includes recoverable copper content of nonduplicative mine and metal products produced from domestic ores and concentrates and leach production for electrowinning.

6/ Recoverable content.

7/ Less than 1/2 unit.

8/ Excludes copper content of pyrite.

9/ Data are for fiscal years beginning April 1 of year stated. Zambian-mined copper reported recovered during smelting and electrowinning.

TABLE 21
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Albania, primary	1,424	--	1,632 r/	1,281 r/	1,300
Australia, primary	261,300	208,400	236,000	334,000 e/	393,000 3/
Austria, secondary e/	65,400	73,000	54,800	77,573 r/ 3/	78,000
Belgium:					
Primary	35,000	38,000	20,700	25,000 e/	20,000
Secondary	153,800	139,000	138,400	143,300	144,700 3/
Total	188,800	177,000	159,100	168,300	164,700 3/
Botswana 4/	20,980 r/	19,820 r/	22,124 r/	20,960 r/	20,977 3/
Brazil, primary	172,075	177,060	167,205	193,014 r/	195,000
Bulgaria:					
Primary	99,398	109,630	114,500	107,000 r/	160,600
Secondary e/	5,000	5,000	5,000	5,000	5,000
Total e/	104,398	114,630	119,500	112,000 r/	166,000
Canada:					
Primary	529,349	529,524	553,100	550,200 r/	543,600 3/
Secondary	83,344	96,957	71,300	66,800 r/	60,100 3/
Total	612,693	626,481	624,400	617,000 r/	603,700 3/

See footnotes at end of table.

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TABLE 21--Continued
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Chile, primary	1,355,600	1,389,600	1,403,100	1,474,000	1,456,500 3/
China: e/					
Primary	616,000	789,000	839,000	837,000 r/	990,000
Secondary	220,000	180,000	170,000	190,000	200,000
Total	836,000	969,000	1,010,000	1,027,000 r/	1,190,000
Congo (Kinshasa), primary: e/					
Electrowon	43,800	40,100	40,000	32,000 r/	21,000
Other	6,000	--	--	--	--
Total	49,800	40,100	40,000	32,000 r/	21,000
Finland:					
Primary	178,675 r/	159,000 r/	156,000 r/	149,600 r/	155,400 3/
Secondary e/	-- r/	2,000	2,000	2,000	2,000
Total e/	178,675 r/ 3/	161,000 r/	158,000 r/	151,600 r/	157,400
France, secondary e/	2,300	2,400	2,000	1,000 r/	--
Germany:					
Primary	296,800	273,000	258,600	266,400	275,000
Secondary e/	88,600	76,000	80,000 3/	60,000	75,000
Total e/	385,000	349,000	338,600 3/	326,000	350,000
Hungary, secondary e/	100	100	--	--	--
India, primary	45,300	51,000	107,600	224,400	225,600 3/
Indonesia	--	--	--	126,739	173,726 3/
Iran: e/ 5/					
Primary	93,100 r/	93,000 r/	144,000 r/	150,000 r/	150,000
Secondary	6,000	6,100	6,000	4,000 r/	4,000
Total	99,100 r/	99,100 r/	150,000 r/	154,000 r/	154,000
Japan:					
Primary	1,122,571	1,214,172	1,171,657	1,256,276	1,331,352 3/
Secondary	110,856	136,274	131,979	133,188	149,282 3/
Total	1,233,427	1,350,446	1,303,636	1,389,464	1,480,634 3/
Kazakhstan	245,000	315,960	335,000 e/	384,234	400,000
Korea, North: e/					
Primary	24,000	24,000	23,000	20,000	20,000
Secondary	5,000	5,000	4,500	5,000	5,000
Total	29,000	29,000	27,500	25,000	25,000
Korea, Republic of	150,000	160,000	293,000	370,000	410,000
Mexico:					
Primary	280,462	348,290	378,302	352,700	323,000
Secondary e/	21,800	4,000	4,000	5,000	5,000
Total	302,262	352,290	382,302	357,700	328,000
Namibia, primary	16,659	24,997 r/	8,014 r/	-- e/	13,488 3/
Norway, primary	28,526 r/	32,639 r/	31,658 r/	33,262	27,000
Oman, primary	24,663	22,800	24,400 r/	16,818 r/	23,790 3/
Peru, primary	345,119 r/	323,382 r/	356,189 r/	350,399 r/	340,447 3/
Philippines, primary	201,661	206,160	198,088	148,000 r/	140,000
Poland:					
Primary	399,800	415,000 e/	422,243	486,384 r/	507,846 3/
Secondary e/	15,000	15,000	10,000	10,000 r/	10,000
Total	415,000 e/	430,500 e/	432,000	468,000	518,000
Romania:					
Primary	32,622	25,024	18,708	24,013 r/	16,500
Secondary e/	1,000	1,000	1,000	2,000	2,000
Total e/	33,600	26,000	19,700	26,000 r/	18,500
Russia: e/					
Primary	550,000	535,000	510,000	540,000	580,000
Secondary	20,000	35,000	40,000	158,000	200,000
Total	570,000	570,000	550,000	698,000	780,000 3/
Serbia and Montenegro:					
Primary e/	59,940 3/	60,000	40,000 r/	54,000	86,000
Secondary	65,287	60,000 e/	55,000 r/	49,780 r/	4,000
Total	125,227	120,000 e/	95,000 r/	103,780 r/	90,000 3/

See footnotes at end of table.

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TABLE 21--Continued
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Slovakia, primary e/	14,000	10,000	10,000	10,000	10,000
South Africa, primary	148,400	163,600	152,300	149,300 r/	126,128 3/
Spain:					
Primary	248,500	288,900	291,400	305,000 e/	264,800 3/
Secondary	22,400	23,800	23,800	25,000 e/	65,000
Total	270,900	312,700	315,200	330,000 e/	329,800
Sweden: e/					
Primary	100,000 3/	95,000 r/	90,000 r/	85,000 r/	95,000
Secondary	26,000 r/ 3/3/	33,000 r/	35,000 r/	30,000 r/	35,000
Total	126,000 r/ 3/	128,000 r/	125,000	115,000 r/	130,000
Turkey 6/	38,600 e/	32,491	35,000	37,000	37,000
United States:					
Primary	1,300,000	1,440,000	1,490,000	1,090,000	W
Secondary	339,000	285,000	232,000	205,000	W
Total	1,640,000	1,720,000	1,720,000	1,290,000	1,000,000 3/
Uzbekistan: e/					
Primary	75,000	80,000	89,900	72,000	75,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	80,000	85,000	94,900	77,000	80,000
Zambia, primary: 7/					
Electrowon	73,900	61,140	51,736	25,000 e/	25,000
Other	250,300	220,327	206,871	184,000 e/	169,500
Total	324,200	281,467	258,607	209,000 e/	194,500
Zimbabwe, primary e/ 8/	18,000 r/	18,000 r/	10,000 r/	10,000 r/	10,000
Grand total:	10,800,000 r/	11,200,000 r/	11,400,000	11,700,000 r/	11,900,000
Of which:					
Primary:					
Electrowon	118,000	101,000	91,700	57,000 r/	46,000
Other	8,930,000 r/	9,360,000 r/	9,520,000 r/	9,500,000 r/	8,730,000 9/
Secondary	1,260,000 r/	1,180,000	1,070,000	1,180,000 r/	1,050,000 9/
Undifferentiated	455,000 r/	528,000 r/	685,000 r/	939,000 r/	2,040,000 9/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included in total. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 20, 2001.

3/ Reported figure.

4/ Copper content of nickel-copper matte exported to Norway for refining.

5/ Data are for year beginning March 21 of year stated. Secondary production is estimated to be about 5% of total.

6/ Secondary production is estimated to be about 5% to 10% of total.

7/ For fiscal year beginning April 1 of year stated. Electrowon is total electrowon production reported less the quantity reported as "finished production, leach cathodes."

8/ Includes impure cathodes produced by electrowinning in nickel processing.

9/ U.S. production undifferentiated in 2000.

TABLE 22
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Albania, primary	1,544 r/	-- r/	1,150 r/	342 r/	350
Argentina, secondary e/	16,000	16,000	16,000	16,000	16,000
Australia, primary	311,400	270,100	285,900	412,000 r/	487,000

See footnotes at end of table.

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TABLE 22--Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Austria: e/					
Primary	1,000	2,000	2,000	2,000	2,000
Secondary	57,000	65,000	76,000	75,000	77,000
Total	58,000	67,000	78,000	77,000	79,000 3/
Belgium: 4/					
Primary	191,000	190,000	185,000	201,000 e/	236,100 3/
Secondary	163,000	183,000	183,000	187,000 e/	187,000
Total	354,000	373,000	368,000	388,000 e/	423,000
Brazil, primary	172,075	177,060	167,200	193,011 r/	185,345 3/
Bulgaria:					
Primary	17,301	29,530	31,400 r/	16,000 r/ e/	25,500
Secondary e/	5,000	5,000	5,000	5,000	5,000
Total	22,301	34,530	36,400 r/	21,000 r/	30,500 3/
Burma, electrowon	--	--	6,700 e/	26,736	26,711 3/
Canada:					
Electrowon	2,500	2,700	1,800	--	--
Primary	475,000	458,400	488,100	480,400 r/	490,100 3/
Secondary	81,700	99,300	72,600	68,200 r/	61,300 3/
Total	559,200	560,400	562,500	548,600 r/	551,400 3/
Chile:					
Electrowon	635,700	881,000	1,108,000	1,361,300	1,372,600 3/
Primary	1,112,500	1,235,600	1,226,900	1,304,300	1,295,700 3/
Total	1,748,200	2,116,600	2,334,900	2,665,600	2,668,300 3/
China: e/					
Primary	692,000	801,000	870,000	836,000 r/	1,060,000
Secondary	428,000	379,000	341,000	338,000 r/	340,000
Total	1,120,000	1,180,000	1,210,000	1,170,000 r/	1,400,000
Congo (Kinshasa), primary 5/	40,147 r/	37,658 r/	38,236 r/	31,225 r/	20,500
Cyprus, electrowon	1,499 r/	4,435 r/	4,936 r/	5,004 r/	5,197 3/
Egypt, secondary e/	4,600	5,000 r/	6,000 r/	6,000 r/	5,000
Finland: e/					
Primary	101,000 r/	100,000	108,000 r/	100,000 r/	100,000
Secondary	10,000	16,000	15,000	15,000	14,000
Total	111,000 r/	116,000	123,000 r/	115,000 r/	114,000
France: e/					
Primary	10,500	--	--	--	--
Secondary	28,600	35,600	22,400	1,800	1,500
Total	39,100	35,600	22,400	1,800	1,500
Germany:					
Primary	316,000 e/	297,900	322,800	271,000 e/	335,000
Secondary	355,000 e/	375,800	373,000	425,000 e/	375,000
Total	671,000 e/	673,700	695,800	696,000 e/	710,000
Hungary, secondary e/	11,000	12,000 r/	12,000 r/	12,000 r/	12,000
India:					
Primary, electrolytic	29,100	30,200	100,000	200,000 e/	234,000
Secondary e/	10,200	6,000	7,000	8,000	9,000
Total e/	39,300	36,200	107,000	208,000	243,000
Indonesia, primary	--	--	--	126,700	173,800 3/
Iran: 6/					
Electrowon	1,500	9,500	14,000	14,000 e/	14,000
Primary 7/	99,100	103,300	129,000 r/	131,700 r/	130,000
Total	100,600	112,800	143,000 r/	146,000 r/ e/	144,000
Italy:					
Primary	25,000	5,600	--	--	--
Secondary	60,800	80,100	29,100 e/	28,000 e/	70,000
Total	85,800	85,700	29,100 e/	28,000 e/	70,000
Japan:					
Primary	1,140,502	1,157,299	1,149,266	1,215,248	1,290,091 3/
Secondary	110,871	121,400	128,086	126,301	147,260 3/
Total	1,251,373	1,278,699	1,277,352	1,341,549	1,437,351 3/

See footnotes at end of table.

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TABLE 22--Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Kazakhstan, primary	267,100	301,100	324,900	361,889	394,722 3/
Korea, North: e/					
Primary	23,000	23,000	23,000	20,000	20,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	28,000	28,000	28,000	25,000	25,000
Korea, Republic of:					
Primary	246,305	265,426	373,205	450,444	470,537 3/
Secondary e/	2,000	2,000	2,000	4,000	4,000
Total e/	248,000	267,000	375,000	454,000	475,000
Mexico:					
Primary:					
Electrowon	45,407	48,217	48,819	50,952	47,800
Other	180,100	234,000 e/	383,181	361,000 r/	340,400 3/
Secondary	16,493	14,783	15,000 e/	14,000 e/	15,000
Total	242,000	297,000	447,000	425,952 r/	403,000
Mongolia, electrowon	--	2,751	2,319	1,545 r/	1,450
Norway, primary 7/	28,526	32,639 r/	31,658 r/	33,262 r/	27,000
Oman, primary	24,150 r/	23,600 r/	22,700 r/	17,171 r/	24,281 3/
Peru:					
Electrowon	88,172	99,738 r/	101,837	114,927 r/	127,310 3/
Primary	249,890	284,347 r/	309,594 r/	318,914	324,416 3/
Total	338,062	384,085 r/	411,431 r/	433,841 r/	451,726 3/
Philippines, primary	155,774	146,630	152,400	147,982 r/	135,000
Poland:					
Primary	404,700 r/	420,600 r/	426,537 r/	448,300	466,002 3/
Secondary e/	20,000	20,000	20,300	22,200 3/	20,000
Total	424,700 r/	440,600 r/	446,837 r/	470,500	486,002 3/
Romania:					
Primary	29,305	22,912	21,028	24,983 r/	13,803 3/
Secondary e/	5,000	4,000	2,000	4,000	4,000
Total	34,305	26,912	23,028	28,983 r/	17,803 3/
Russia:					
Primary	543,000	535,000	543,000	600,000	640,000
Secondary	57,000	65,000	77,000	150,000	200,000
Total	600,000	600,000	620,000	750,000	840,000
Serbia and Montenegro:					
Primary	59,940	70,534	49,346 r/	48,002 r/	45,602 3/
Secondary	44,060	43,000	45,000 e/	1,900 r/ e/	40,000
Total	104,000	113,534	94,346 r/	49,902 r/	85,600
Slovakia, primary and secondary e/	28,000	31,400 r/	24,100	21,000	20,000
South Africa, primary 7/	123,000	130,200	125,600	116,400 r/	100,500
Spain: e/					
Primary	210,000	229,000 r/	239,600 r/ 3/	250,756 r/ 3/	250,800 3/
Secondary	54,000	63,300	64,730 r/	65,000 r/	65,000
Total	264,000	292,000	304,330 r/ 3/	315,756 r/ 3/	315,800 3/
Sweden: e/					
Primary	100,000	105,000	100,000	95,000	105,000
Secondary	25,000	23,000 3/	25,000	20,000	25,000
Total	125,000 3/	128,000 3/	125,000	115,000	130,000
Taiwan, secondary e/	6,000	4,000	4,000	4,000	4,000
Turkey:					
Primary	80,700	102,100	82,800	69,000 e/	62,000
Secondary	20,000	9,300	9,000	9,000 e/	10,000
Total	100,700	111,400	91,800	78,000 e/	72,000
United Kingdom:					
Primary	12,869	9,100	8,000	5,000 e/	1,000
Secondary	43,746	51,300	44,000	45,000 e/	49,000
Total	56,615	60,400	52,000	50,000 e/	50,000

See footnotes at end of table.

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TABLE 22--Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
United States:					
Primary:					
Electrowon	574,000	586,000	609,000	586,000	557,000 3/
Other	1,430,000	1,480,000	1,530,000	1,300,000	1,030,000 3/
Secondary	345,000	396,000	349,000	230,000	208,000 3/
Total	2,350,000	2,470,000	2,490,000	2,120,000	1,790,000 3/
Uzbekistan: e/					
Primary	95,000	105,000	89,930 3/	72,000	75,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	100,000	110,000	94,930	77,000	80,000
Zambia, primary: 8/					
Electrowon	58,000	63,736	80,709	57,000 e/	55,000
Other	276,000	268,553	248,820	176,000 e/	170,000
Total	334,000	332,289	329,529	233,000 e/	225,000
Zimbabwe: e/					
Electrowon	3,200	2,900	2,400	1,020 r/	--
Primary	10,900	4,990	2,940	7,000 r/	7,200
Secondary	6,000	--	--	--	--
Total	20,100	7,890	5,340	8,020 r/	7,200
Total, primary	10,700,000	11,400,000	12,200,000	12,700,000 r/	13,000,000
Total, secondary	1,980,000	2,090,000	1,940,000 r/	1,880,000	1,960,000
Total, primary and secondary, undifferentiated	39,000	43,400 r/	36,100 r/	33,000 r/	32,000
Grand total	12,700,000	13,500,000	14,200,000 r/	14,600,000 r/	15,000,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. Table includes data available through July 20, 2001.

3/ Reported figure.

4/ Includes reprocessed leach cathode from Congo (Kinshasa).

5/ Excludes leach cathode exported for processing in Belgium.

6/ Data are for Iranian years beginning March 21 of that stated.

7/ May include secondary.

8/ Data are for fiscal year beginning April 1 of that stated. Electrowon covers only presumably high-grade electrowon cathodes reported as "finished production leach cathodes." Other, in addition to electrowon cathodes, includes a smaller amount of "finished product shapes" presumably cast from electro-refined cathodes, or any blister-anodes and low-anodes and low-grade electrowon cathodes that were furnace- or fire-refined.

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DIAMOND, INDUSTRIAL

By Donald W. Olson

Domestic survey data and tables were prepared by Christine K. Pisut, statistical assistant, and the world production tables were prepared by Regina R. Coleman, international data coordinator.

Diamond is best known for its gem qualities, but some of its unique properties make it ideal for many industrial and research applications as well. Current information on gem-grade diamond can be found in the U.S. Geological Survey minerals yearbook chapter on gemstones. Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature (May, 1995). Diamond is more than twice as hard as cubic boron nitride or silicon nitride, which are the nearest competitors (Ravi, 1994, p. 537). Because it is the hardest substance known, diamond has been used for centuries as an abrasive in grinding, drilling, cutting, and polishing, and industrial-grade diamond continues to be used as an abrasive for many applications. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Even though it has higher unit cost, diamond has proven to be more cost effective in many industrial processes because it cuts faster and lasts longer than its rival abrasive materials (Boucher, 1997, p. 26.6). Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, and advanced technologies.

Both synthetic and natural diamonds have industrial uses, but synthetic industrial diamond is superior to its natural counterpart because it can be produced in large quantities. In many cases, its properties can be tailored to specific applications (Boucher, 1996). It is for these reasons that manufactured diamond accounts for more than 90% of the industrial diamond used in the United States and the world.

Legislation and Government Programs

Congress has authorized the sale of all the diamonds in the National Defense Stockpile (NDS), which is managed by the Department of Defense (DOD). The NDS 2000 annual plan allowed for the sale of a portion of the stockpiled diamond stones. During 2000, the Defense National Stockpile Center (DNSC) sold 989,140 carats of diamond stone (valued at $33.44 million). At yearend 2000, the DNSC reported an NDS remaining inventory of about 1.508 million carats of industrial diamond stone valued at $15.08 million (Defense National Stockpile Center, 2000a, 2000b). The DOD plans to conduct additional future sales until all NDS diamond stone stocks are exhausted. Further NDS information is available in the "Prices" section of this report.

Production

The U.S. Geological Survey conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 2000 survey, a few significant firms withheld certain data that they deemed confidential. Thus, only estimates of U.S. primary and secondary output are provided in this review.

Industrial Diamond in the 20th Century

The utilitarian role of diamond was confined to lapidary products until industrialization created the first demand for diamond as an industrial tool for precision cutting and as abrasive material set in saw blades and drill bits. Few statistical data are available on abrasive diamond prior to 1911, when the United States imported $110,434 in diamond dust and bort, primarily from South Africa. After World War I, with the development of cemented carbide cutting tools, diamond was found to be the most effective medium for finishing and grinding the new ultrahard metal. This discovery rapidly increased the demand for industrial diamond. There was almost no U.S. diamond production until the early 1930s, when a relatively small diamond deposit near Murfreesboro, AR, was developed. By 1937, about two-thirds, by weight, of all diamond sold each year was used for abrasive purposes, and U.S. imports of abrasive diamond, primarily from South Africa and Brazil, were valued at just under $7 million. World War II, with its increased use of hard-metal tools in the munitions industry, further increased the demand for industrial diamond.

In 2000, synthetic diamond accounted for more than 90% of the industrial diamond market. The United States was the world's largest market for industrial diamond, as well as the largest producer of synthetic industrial diamond, with estimated production of 248 million carats. In 2000, U.S. imports of an estimated 293 million carats of industrial diamond stone, bort, grit, dust, and powder, primarily from Belgium, Ireland, Switzerland, and the United Kingdom, were valued at about $125 million. In 1955, General Electric Co. announced that its laboratories had succeeded in manufacturing synthetic diamond from carbonaceous material. Economic commercial production of synthetic industrial diamond was achieved by the early 1960s. The manufacture and use of synthetic diamond steadily increased. By the end of the 1960s, domestic production of synthetic industrial diamond had increased to 13 million carats per year, and by the early 1980s, production had reached 57 million carats per year. In 2000, synthetic industrial diamond could be made in a relatively short time, and its performance in specific end-use applications exceeded that of natural diamond.

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As one of the world's leading producers of synthetic industrial diamond, the United States accounted for an estimated output of 248 million carats in 2000. Only two U.S. companies produced synthetic industrial diamond during the year—Mypodiamond, Inc., Gibbstown, NJ, and GE Superabrasives, Worthington, OH. General Electric Co., Fairfield, CT, which owns GE Superabrasives and other diamond manufacturing plants abroad, is one of the world's largest producers of industrial diamond.

In 2000, nine firms also manufactured polycrystalline diamond (PCD) from synthetic diamond grit and powder. These companies were the Dennis Tool Co., Houston, TX; GE Superabrasives, Worthington, OH; Novatek Inc., Provo, UT; Phoenix Crystal Corp., Ann Arbor, MI; Precorp Inc., Provo, UT; SII Megadiamond Industries Inc., Provo, UT; Tempo Technology Corp., Somerset, NJ; U.S. Synthetic Corp., Orem, UT; and Western Diamond Products, Salt Lake City, UT.

It is estimated that more than 10.1 million carats of used industrial diamond were recycled in the United States during 2000. Most of this material was recovered by recycling firms from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD; most of this material was recovered for PCD from within the production operations of the PCD producing companies (Wilson Born, National Research Company, oral commun., 2001).

The recovery and sale of industrial diamond was the principal business of four U.S. companies in 2000: Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston, TX; and National Research Company, Fraser, MI. In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

Consumption

The United States remained the world's largest market for industrial diamond in 2000. Based on production estimates and trade data, the apparent U.S. consumption of industrial diamond during the year increased to an estimated 484 million carats, which was a record high. This growth primarily reflects expanded output in many domestic industries where diamond is used. The major consuming industries of industrial diamond in the United States during 2000 were construction, machinery manufacturing, mining services (drilling), stone cutting/polishing, and transportation systems (infrastructure and vehicles). Within these sectors, stone cutting and highway building/repair together made up the largest demand for industrial diamond. The manufacture of every automobile made in the United States consumes 1.5 carats of industrial diamond. Research and high technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks for electronic circuits, lenses for laser radiation equipment, and polishing silicon wafers and disk drives in the computer industry (Bailey and Bex, 1995).

Diamond tools have myriad industrial functions. Diamond drilling bits and reaming shells are used principally for gas, mineral, and oil exploration. Other applications of diamond bits and reaming shells include foundation testing, masonry drilling, and inspecting concrete in various structures. The primary uses of point diamond tools are for dressing and truing grinding wheels and for cutting, machining, boring, and finishing; beveling glass for automobile windows is another application. Cutting dimension stone and cutting/grooving concrete in highway reconditioning are the major uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry: diamond stone (generally larger than 60 mesh/800 microns) and diamond bort (smaller, fragmented material). Diamond stone is employed primarily in drilling bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drilling bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include engraving points, glass cutters, bearings, and surgical instruments.

Synthetic diamond grit and powder are used in diamond grinding wheels, saws, impregnated bits and tools, and as loose abrasive compounds for polishing. Diamond grinding wheels can be as much as 1 meter in diameter.

Loose powders and compounds made of synthetic diamond for polishing are used primarily to finish optical surfaces, jewel bearings, gemstones, wiredrawing dies, cutting tools, and silicon wafers for computer chips. Hundreds of other products made from metals, ceramics, plastics, and glass also are finished with diamond powders and compounds.

The use of polycrystalline diamond shapes (PDS) and polycrystalline diamond compacts (PDC) continues to increase for many of the applications cited above, including some of those that employ natural diamond. The use of PDS, PDC, and matrix-set synthetic diamond grit for drilling bits and reaming shells has increased in recent years. PDS and PDC are used in the manufacture of single- and multiple-point tools, and PDC is used in a majority of the diamond wire-drawing dies.

Prices

Natural and synthetic industrial diamonds differ significantly in price (Boucher, 1997, p. 26.6). Natural industrial diamond normally has a more limited range of values. Its price varies from about $0.45 per carat for bort-size material to about $7 to $25 per carat for most stone. Synthetic industrial diamond has a much larger range of prices than natural diamond. Prices of synthetic diamond vary according to size, shape, crystallinity, and the absence or presence of metal coatings. In general, synthetic diamond prices for grinding and polishing range from as low as $0.10 per carat to $0.95 per carat. Strong and blocky material for sawing and drilling sells for $1.50 to $4.75 per carat. Large synthetic crystals with excellent structure for specific applications sell for several hundred dollars per carat.

In 2000, the DNSC had awarded bids that ranged from $1.44 to $151.00 per carat for NDS diamond stone sold, with the average awarded bid being $33.80 per carat (Defense National Stockpile Center, 2000a, b).

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Foreign Trade

The United States continued to lead the world in industrial diamond trade during 2000; imports came from 36 countries (tables 1, 2), and exports/reexports went to 55 countries (tables 3, 4). Although the United States has been a major producer of synthetic diamond for decades, its growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations, because domestic production of natural diamond was unable to meet demand.

During 2000, U.S. imports of industrial quality diamond stones (natural and synthetic) decreased by 20% from 1999 imports to 2.52 million carats valued at $13.4 million (table 1). Imports of diamond powder, dust, and grit (natural and synthetic) increased by 39% from 1999 imports to 291 million carats valued at $111 million (table 2).

During 2000, U.S. exports and reexports of industrial diamond stone decreased by approximately 9% from 1999 exports and reexports to 3.62 million carats valued at $34.6 million (table 3). Additionally, U.S. exports and reexports of industrial diamond powder, dust, and grit decreased slightly from 1999 exports and reexports to 100 million carats valued at $71.8 million (table 4). Reexports can account for a significant portion of total exports/reexports; therefore, exports and reexports are listed separately in tables 3 and 4 so that U.S. trade and consumption can be calculated more accurately.

World Review

Total industrial diamond output worldwide during 2000 was estimated to be well above 800 million carats; analyst reports estimated that global output, which was valued between $600 million and $1 billion, was at least 600 million carats (Norman Rohr, Warren Diamond Powder Co., Inc., oral commun., 1999; Wilson Born, National Research Company, oral commun., 2000). World demand for industrial diamond in the 1990s had been growing at rates of more than 10% per year (Boucher, 1997, p. 26.6).

Industrial diamond was produced in 30 countries during 2000 (tables 5, 6). In addition to the countries listed in table 6, Germany and the Republic of Korea produced synthetic diamond (Norman Rohr, Warren Diamond Powder Co., Inc., oral commun., 1999), but specific data on their output could not be confirmed. China may have produced much more than the output shown in the table (Owers, 2000; Wilson Born, National Research Company, oral commun., 2001).

In 2000, approximately 70% of the total global natural and synthetic industrial diamond output was produced in Ireland, Russia, and the United States. The dominance of synthetic diamond was even more pronounced, accounting for more than 90% of global production and consumption.

The Ekati Mine, Canada's first commercial diamond mine, completed its second full year of production. The Ekati Mine, located in the Northwest Territories, was a joint venture between BHP Diamonds Inc. (BHP) and Dia Met Minerals Ltd., but in June 2001, BHP purchased Dia Met Minerals Ltd. (BHP Diamonds Inc., 2001). Ekati has estimated reserves of 60.3 million metric tons (Mt) of ore in kimberlite pipes, containing 54.3 million carats of diamonds, and the mine life is projected to be 25 years. In 2000, Ekati produced 2.63 million carats (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, Senior Project Geologist, BHP Diamonds Inc., oral commun., May 27, 2001).

Two other Canadian commercial diamond mines located in the Northwest Territories are expected to commence diamond production in the first half of 2003. They are the Diavik diamonds project and the Snap Lake diamond project. Diavik has estimated reserves of 25.6 Mt of ore in kimberlite pipes, containing 102 million carats of diamonds, and the mine life is projected to be 20 years. Diavik is expected to produce about 102 million carats of diamond at a rate of 6 million carats per year worth about $63 per carat (Diavik Diamond Mines Inc., 2000, p. 10-12). The Snap Lake diamond project was acquired by De Beers Canada Mining Inc. from Winspear Diamonds Inc. and Aber Diamond Corporation in 2000. Snap Lake will be De Beers' first mine outside of southern Africa and the first underground diamond mine in Canada. Snap Lake has estimated reserves of 22.8 Mt of ore in a kimberlite dike, containing 38.8 million carats of diamonds, and the mine life is projected to be 20 years or more (De Beers Canada Mining Inc., 2000, Snap Lake diamond project fact sheet, accessed June 13, 2001, at URL http://www.debeerscanada.com/files_new/snap/infrastruct.html).

Diamond exploration is continuing in Canada, and many new deposits are being found. There have been additional discoveries in both the core and buffer zones of the Ekati lease. At least 35 kimberlites have been discovered in north-central Alberta, and 70 large kimberlites have been found in Saskatchewan. Additional discoveries have been made in Ontario and Quebec (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm). When the Diavik and Snap Lake mines begin production, Canada will be producing at least 15% to 20% of the total world natural diamond production. This will make Canada a significant producer of natural industrial diamond, as well as of gem-quality diamond.

Outlook

The United States will continue to be the world's largest market for industrial diamond well into the next decade, and it will remain a significant producer and exporter of industrial diamond.

The strength of U.S. demand will depend on the vitality of the Nation's industrial base and on how well the life cycle cost effectiveness of diamond compares with competing materials that initially are less expensive. The many advantages that diamond offers for precision machining and longer tool life, which compensate for increases in other production line costs, seem certain to spur demand for diamond tools. In fact, even the use of wear-resistant diamond coatings to increase the life of materials that compete with diamond promises to be a rapidly growing application (May, 1995). Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer unattended production runs (Advanced Materials & Processes, 1998). In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability by a factor of 50 (Advanced Materials & Processes, 1998), much wider use of diamond as an

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engineering material is expected.

The most dramatic increase in U.S. demand for industrial diamond is likely to occur in the construction sector as the $200 billion Transportation Equity Act for the 21st Century (Public Law 105-178, enacted June 9, 1998) is further implemented. The act provides funding for building and repair of the Nation's highway system through 2003. Demand for saw-grade diamond alone is expected to increase by more than $1 billion during the coming year to fulfill goals mandated by the act for the repair and replacement of roads, bridges, and other components in the transportation infrastructure of the country (Wilson Born, National Research Company, oral commun., 2001).

According to industry sources, PCD for abrasive tools and wear parts will continue to replace competing materials in many industrial applications by providing closer tolerances, as well as extending tool life. For example, PDC and PDS will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries (Wilson Born, National Research Company, written commun., 1998).

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. The stone cannot be manufactured commercially. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

World demand for industrial diamond will continue to increase during the next few years. Constant-dollar prices of synthetic diamond products, including chemical-vapor-deposition diamond films, will decline as production technologies become more cost-effective and competition increases from low-cost producers in China and Russia.

References Cited

Advanced Materials & Processes, 1998, Diamond coating increases carbide tool life by 50x: Advanced Materials & Processes, v. 154, no. 2, August, p. 20.

Bailey, M.W., and Bex, P.A., 1995, Industrial diamond—A brief history, a long future: Finer Points, v. 7, no. 4, p. 35-39.

Boucher, Michel, 1996, Overview of the diamond industry, *in* Industrial Minerals '96, Toronto, 1996, Proceedings: Toronto, Blendon Information Services, [unpaginated].

———1997, Diamonds: Ottawa, Canadian Minerals Yearbook 1996, p. 26.1-26.19.

Defense National Stockpile Center, 2000a, Stockpile awards diamond stones: Fort Belvoir, VA, Defense National Stockpile Center news release, April 19, 6 p.

———2000b, Stockpile awards diamond stones: Fort Belvoir, VA, Defense National Stockpile Center news release, August 3, 6 p.

Diavik Diamond Mines Inc., 2000, Diavik annual social and environmental report—2000: Yellowknife, NT, Diavik Diamond Mines Inc., 74 p.

May, P.W., 1995, CVD diamond—A new technology for the future: Endeavour Magazine, v. 19, no. 3, p. 101-106.

Owers, Chris, 2000, Industrial diamond—Applications, economics and a view to the future: Industrial Diamond Review, v. 60, no. 586, p. 176-181.

Ravi, K.V., 1994, Technological applications of CVD diamond, *in* Spear, K.E., and Dismuks, J.P., eds., Synthetic diamond—Emerging CVD science and technology: John Wiley & Sons, Inc., New York, p. 533-580.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Abrasives. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Diamond (Industrial). Ch. in Mineral Commodity Summaries, annual.

Gemstones. Ch. in Minerals Yearbook, annual.

Diamond, Industrial. Ch. in Minerals Yearbook, annual.

Other

De Beers Consolidated Mines Ltd., annual report, 1998, 1999, 2000.

Diamond, Industrial. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines, Bulletin 675, 1985.

Finer Points (quarterly).

Industrial Diamond Review (bimonthly).

World Diamond Industry Directory & Yearbook 1998-99.

TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Natural industrial diamond stones 2/				Miners' diamond, natural and synthetic 3/			
	1999		2000		1999		2000	
Country	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/
Belgium	144	2,980	111	334	53	846	41	567
China	2	14	2	7	1	13	9	10
Congo (Kinshasa)	25	30	1	10	--	--	1	22
Ghana	159	672	67	292	49	772	57	352
India	4	27	33	46	--	--	(5/)	5
Ireland	203	594	322	757	1	23	31	94
South Africa	36	51	8	36	(5/)	10	1	71
Switzerland	3	48	5	76	676	1,170	691	940
United Kingdom	398	517	489	330	215	4,900	338	8,390
Other	835	1,300	117	499	328	343	198	521
Total	1,810	6,230	1,150	2,390	1,320	8,090	1,370	11,000

See footnotes at end of table.

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TABLE 1–Continued
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000.
3/ HTS codes 7102.21.1010 and 7102.21.1020.
4/ Customs value.
5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND POWDER, DUST AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Synthetic 2/				Natural 2/			
	1999		2000		1999		2000	
Country	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
Belgium	2,130	1,580	1,890	946	4,500	3,730	6,400	4,440
China	33,500	6,040	37,700	5,220	227	173	3,140	281
France	--	--	20	27	--	--	--	--
Germany	75	58	2,390	3,320	78	81	144	69
Ghana	87	53	93	31	257	194	69	117
Hong Kong	217	121	1,550	161	--	--	--	--
India	1,820	519	2,240	585	1,350	393	1,150	394
Ireland	97,000	56,400	140,000	69,900	2,250	1,670	2,070	984
Japan	4,420	2,800	6,540	3,040	401	588	913	1,640
Korea, Republic of	9,860	6,460	11,000	6,640	11	6	--	--
Russia	5,220	1,180	6,230	1,330	23	4	62	16
Switzerland	3,570	3,020	3,300	1,780	1,520	1,090	1,840	1,250
United Kingdom	2,070	950	4,150	1,140	1,440	412	815	293
Other	34,300	4,450	56,900	7,420	2,230	293	390	403
Total	194,000	83,700	274,000	102,000	14,300	8,630	17,000	9,890

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States codes: synthetic, 7105.10.0020, 7105.10.0030, and 7105.10.0050; natural, 7105.10.0011 and 7105.10.0045.
3/ Customs value.

Source: U.S. Census Bureau.

TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Industrial unworked diamonds 2/			
	1999		2000	
Country	Quantity	Value 3/	Quantity	Value 3/
Exports:				
Belgium	17	141	320	3,940
Canada	117	410	237	845
Germany	79	473	52	366
Hong Kong	5	41	50	504
Ireland	7	47	3	32
Israel	--	--	42	419
Italy	--	--	9	13
Japan	351	3,480	446	4,220
Korea, Republic of	80	713	64	649
Netherlands	1	12	1	14
Switzerland	12	118	10	100
United Kingdom	16	157	6	50
Other	61	491	320	2,150
Total	746	6,080	1,560	13,300

See footnotes at end of table.

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TABLE 3--Continued
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

Country	Industrial unworked diamonds 2/			
	1999		2000	
	Quantity	Value 3/	Quantity	Value 3/
Reexports:				
Belgium	2,700	25,400	1,180	13,100
Canada	64	278	66	214
Germany	15	150	89	504
Hong Kong	12	123	10	48
Ireland	10	99	33	237
Israel	129	1,630	190	2,020
Japan	110	1,150	124	1,270
Korea, Republic of	92	833	75	787
Netherlands	4	43	2	23
Switzerland	1	7	256	2,700
United Kingdom	27	257	12	119
Other	57	580	26	240
Total	3,220	30,600	2,060	21,300
Grand total	3,970	36,700	3,620	34,600

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States code 7102.21.0000.
3/ Customs value.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST, AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

Country	Synthetic 2/				Natural 2/			
	1999		2000		1999		2000	
	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
Exports:								
Australia	50	53	73	81	--	--	7	10
Austria	2,670	1,480	2,150	1,420	312	138	426	315
Belgium	1,430	827	1,690	841	237	157	273	284
Brazil	1,890	1,010	2,050	1,070	--	--	--	--
Canada	1,370	1,420	1,470	1,950	89	180	163	248
China	185	59	2	3	183	31	49	11
France	153	57	586	135	51	114	183	57
Germany	4,790	2,530	4,460	2,720	199	104	384	144
Hong Kong	482	395	882	540	147	52	102	125
India	3,230	1,180	1,400	564	104	56	11	3
Ireland	27,400	25,400	28,700	26,300	258	69	68	52
Israel	481	192	819	318	142	29	157	52
Italy	1,860	842	1,450	546	188	108	200	219
Japan	19,100	10,800	23,300	13,200	414	590	905	1,990
Korea, Republic of	12,100	5,920	13,100	6,630	969	445	262	165
Luxembourg	35	13	20	7	119	79	117	92
Macao	30	17	6	7	22	7	--	--
Malaysia	447	173	653	481	--	--	2	6
Mexico	1,020	840	429	218	66	73	133	78
Singapore	1,210	287	124	70	3	10	5	9
Switzerland	1,920	1,230	1,490	1,260	787	1,190	2,820	3,590
Taiwan	5,840	2,930	1,700	1,540	355	95	94	193
Thailand	368	210	133	96	24	23	2	4
United Kingdom	2,250	1,460	2,870	1,040	2,110	1,500	496	284
Other	1,180	693	979	804	137	125	509	437
Total	91,500	60,000	90,600	61,800	6,920	5,180	7,370	8,370

See footnotes at end of table.

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TABLE 4--Continued
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST, AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Synthetic 2/				Natural 2/			
	1999		2000		1999		2000	
Country	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
Reexports:								
Austria	--	--	156	29	--	--	55	11
Belgium	189	255	9	13	2	7	9	25
Bermuda	--	--	--	--	--	--	2	5
Canada	361	755	539	755	50	101	41	50
China	23	29	--	--	--	--	--	--
France	--	--	--	--	--	--	7	5
Germany	--	--	31	20	--	--	1	3
Hong Kong	337	347	130	49	--	--	35	14
India	--	--	34	6	1,350	1,190	89	223
Ireland	2	9	125	99	--	--	44	32
Israel	--	--	10	3	--	--	--	--
Italy	--	--	19	5	--	--	--	--
Japan	212	114	130	53	--	--	16	40
Korea, Republic of	25	18	249	70	--	--	--	--
Luxembourg	--	--	--	--	--	--	13	12
Malaysia	121	27	38	9	--	--	--	--
Mexico	23	47	35	17	1	5	24	13
Poland	--	--	4	3	--	--	2	4
Switzerland	3	4	--	--	--	--	--	--
Taiwan	--	--	19	14	--	--	7	5
Thailand	16	9	37	20	4	13	--	--
United Kingdom	88	24	21	27	9	11	71	18
Total	1,400	1,640	1,590	1,190	1,410	1,320	416	459
Grand total	92,900	61,600	92,200	63,000	8,330	6,500	7,790	8,830

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States codes: synthetic, 7105.10.0025; natural, 7105.10.0010.
3/ Customs value.

Source: U.S. Census Bureau.

TABLE 5
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1996	1997	1998	1999	2000
Gemstones: 3/					
Angola	2,250	1,110	2,400	3,700 r/	5,400
Australia	18,897 4/	18,100	18,400	13,403 4/	12,014 4/
Botswana	12,388 r/ 4/	15,111 r/ 4/	14,772 r/ 4/	16,000 r/	19,700
Brazil	200	300	300	300	300
Canada	--	--	300	2,000	2,000
Central African Republic	350	400	330	400	400
China	230	230	230	230	230
Congo (Kinshasa)	3,300 r/	3,300 r/	5,080 r/	4,120 r/	3,500
Cote d' Ivoire	202	207	210	210	200
Ghana	142	664	649	518 r/	178
Guinea	165	165	300	410 r/	410
Liberia	60	80	150	120 r/	120
Namibia	1,402 4/	1,350 r/	1,390 r/	1,550 r/	1,520
Russia	10,500	11,200 r/	11,500	11,500	11,600
Sierra Leone	162 4/	300	200	450 r/	450
South Africa	4,400	4,500	4,300	4,000	4,300
Venezuela	99	158	80 r/	59 r/	60
Zimbabwe	300	321	10	15 r/	7
Other	165	124 r/	106	207 r/	258
Total	55,200 r/	57,600 r/	60,800 r/	59,200 r/	62,600

See footnotes at end of table.

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TABLE 5--Continued
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1996	1997	1998	1999	2000
Industrial:					
Angola	250	124	364	400 r/	600
Australia	23,096 4/	22,100	22,500	16,381 4/	14,684 4/
Botswana	5,000	5,000	5,000	5,350 r/	4,950
Brazil	600	600	600	600	600
Central African Republic	120	100	200	150	150
China	900	900	900	920	920
Congo (Kinshasa)	18,940 r/ 4/	18,677 r/ 4/	21,000 r/	16,000 r/	14,200
Cote d' Ivoire	100	100	100	100	100
Ghana	573	166	160	128 r/	712
Guinea	40	40	100	140 r/	140
Liberia	90	120	150	80 r/	80
Namibia	--	71	73	89 r/	80
Russia	10,500	11,200 r/	11,600	11,500	11,600
Sierra Leone	108	100	50	150 r/	150
South Africa	5,550	5,540	6,460	6,020 r/	6,480
Venezuela	73	90	17 r/	36 r/	40
Zimbabwe	137	100	19	30 r/	13
Other	120	105	97	141 r/	143
Total	66,200 r/	65,100 r/	69,300 r/	58,200 r/	55,600
Grand total	121,000 r/	123,000 r/	130,000 r/	117,000 r/	118,000

r/ Revised. -- Zero.
1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through May 25, 2001.
3/ Includes near- and cheap-gem qualities.
4/ Reported figure.

TABLE 6
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/

(Thousand carats)

Country	1996	1997	1998	1999	2000
Belarus	25,000	25,000	25,000	25,000	25,000
China	15,500	16,000	16,500	16,500	16,800
Czech Republic	5,000	5,000	5,000	3,000	--
France	3,000	3,500	3,000	3,000	3,000
Greece	750	750	750	750	750
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	32,000	32,000	32,000	32,000	33,000
Poland	250 4/	260	210	200	--
Romania	5,000	5,000	3,000	3,000	--
Russia	80,000	80,000	80,000	80,000	80,000
Slovakia	5,000	5,000	5,000	3,000	--
South Africa	60,000	60,000	60,000	--	--
Sweden	25,000	25,000	25,000	25,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	114,000	125,000	140,000	208,000	248,000
Total	439,000	451,000	463,000	467,000	495,000

-- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through May 25, 2001.
3/ In addition to the countries listed, the Republic of Korea also produced significant amounts of synthetic diamond, but output was not officially reported, and available information is inadequate to formulate reliable estimates of output levels.
4/ Reported figure.

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DIATOMITE

By Thomas P. Dolley

Domestic survey data and tables were prepared by Shantae F. Hawkins, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Production of diatomite in the United States decreased by about 9% to 677,000 metric tons (t), and its value decreased by about 3% to $173 million free on board (f.o.b.) plant in 2000, compared with 747,000 t valued at $178 million f.o.b. plant in 1999 (table 1). U.S. production of diatomite in 2000 was the lowest since 1994. The decline in production of diatomite can be attributed in part to the decline of growth of the economy and increased energy costs in late 2000 and early 2001. Mining operations that include energy costs associated with calcining, such as diatomite, were affected, particularly in California (Industrial Minerals, 2001). Despite the production decrease, the United States remained the world's largest producer and consumer of diatomite. Used primarily for filtration, major diatomite products were sold as various grades of calcined powders (table 2).

Description and Terminology

Diatomite is a chalk-like, soft, friable, earthy, very fine-grained, siliceous sedimentary rock, usually light in color (white if pure, commonly buff to gray in situ, and rarely black). It is very finely porous, very low in density (floating on water at least until saturated), and essentially chemically inert in most liquids and gases. It also has low thermal conductivity and a rather high fusion point. Diatomaceous earth (often abbreviated as D.E.) is a common alternate name but more appropriate for the unconsolidated or less lithified sediment. The deposits result from an accumulation in oceans or fresh waters of the amorphous hydrous silica (opal, $SiO_2.nH_2O$) cell walls of dead diatoms, which are microscopic single-cell, often colonial aquatic plants (algae). The diatom cells contain an internal, elaborate siliceous skeleton consisting of two valves (frustules), which fit together much like a pill box. The diatom's fossilized skeletal remains vary in size from less than 1 micrometer to more than 1 millimeter but are typically 10 to 200 micrometers across and have a broad variety of delicate, lacy, perforated shapes from spheres and cylinders to discs, ladders, feathers, and needles. Each deposit has characteristic assemblages that have been used to identify the source of material for forensic purposes. There are more than 10,000 species of extinct and living diatoms, some of which live in ice or hot springs as well as marshes or even on moist bark, but they are most abundant in sunlit water—fresh or salt—constantly enriched with suitable nutrients and dissolved silica. Live cells are covered by a jelly, and masses appear as brownish water or films on-stream bottoms. Extensive blooms of diatoms (algae) in coastal waters have caused severe pollution and anoxic conditions, and some species produce domoic acid, a nerve poison that, if ingested, quickly causes death to many animals (Eureka, November 12, 1998, Diatoms—Nature's marbles, accessed May 4, 2000, at URL http://hjs.geol.uib.no/diatoms).

Diatomite is also known as kieselgur (a German name compounded from the words for flint and for an earthy sediment in water) and as tripolite after a diatomite occurrence near Tripoli, Libya. Tripolite is used in some government trade documents as the short name for a longer description of "siliceous fossil meals and similar siliceous earths...;" the short name is used more generally in the various tariff codes that cover diatomite (U.S. International Trade Commission, January 25, 2001, Harmonized Tariff Schedule of the United States—Section V—Chapter 25, accessed June 13, 2001, at URL http://dataweb.usitc.gov/scripts/tariff/0101c25.pdf). An impure (up to 30% clay) Danish variety of diatomite is called moler.

Analysis of oven-dried samples of crude ore from many commercial operations typically shows 80% to 90% (in some

Diatomite in the 20th Century

By 1900, diatomite already had a variety of uses such as in building materials, polishing compounds, filtration, filler material in rubber, paint, roofing, and paper—a prelude to its worldwide use in the 20th century. The first discovery of diatomite in North America was made by J.W. Bailey in 1839 near West Point, NY. Alfred Nobel's invention of dynamite in 1867 resulted in the development of the world's first significant diatomite industry, as diatomite was used as an absorbent and stabilizer for dynamite and nitroglycerine. Dynamite and nitroglycerine explosives required significant amounts of diatomite and operations began to flourish. In 1900, the first U.S. patent was issued for the use of diatomite in beer filtration, which is one of diatomite's primary applications in modern times. Production of diatomite in the United States for 1900 was about 3,280 metric tons. The development of processing techniques during the 1920s (such as calcination, flux calcination, grade and sizing technologies) enabled diatomite to be used in a variety of market applications and end uses.

In 2000, the United States was the world's largest producer and consumer of diatomite, producing 677,000 tons, which accounted for about 36% of global production. Western States were the primary source of U.S. production of diatomite, the largest amount coming from the diatomite deposits of Lompoc, CA. Major diatomite products were sold as various grades of calcined powders. Diatomite continued to be used primarily for filtration (beer, cooking oils, wine), while other major uses were as absorbents, filler applications, insulation, and in cement manufacturing. China was the United States' main production competitor.

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cases 95%) silica (SiO_2) plus alumina (2% to 4%, attributed mostly to clay minerals) and hematite (0.5% to 2%), with an analytical ignition loss of 4% to 6%. Apparent oven-dry block density is 320 to 640 grams per liter (g/L) (compared to 1,000 g/L for water) with 80% to 90% voids. In-place ore contains from 10% to as much as 65% water (2% to 10% in the opaline structure). Dry crude rock can absorb from 1.5 to more than 3 times its weight in water. Dry powdered natural rock has an apparent density of 80 to 250 g/L. The melting point of diatomite ranges from 1,000° C to 1,750° C (Durham, 1973; Breese, 1994).

World reserves are estimated to be 800 million metric tons (Mt), which is 400 times the current estimated annual world production of 2 Mt (table 5). Of the 800 Mt, 250 Mt are in the United States (Antonides, 1999). The world reserve base was estimated by the U.S. Bureau of Mines in 1985 to be almost 2 billion tons (Meisinger, 1985). A resource estimate based just on the dimensions of the deposits near Lompoc, CA, suggests that collectively they could meet the world's current needs for centuries. Data on reserves, however, which are defined as being currently economic using proven practices among other qualifications (U.S. Bureau of Mines and U.S. Geological Survey, 1980), are not readily available and are difficult to calculate because, in addition to considerable variation in physical and chemical properties between and even within deposits, the particular potential use and proximity to a market are major considerations.

Commercial deposits worldwide are reported as mostly freshwater lake (lacustrine) deposits of Miocene to Pleistocene age, formed between 24 million to 10 thousand years ago. The reputed world's largest producing deposit that outcrops near Lompoc is a huge marine deposit of Miocene age. Although known marine occurrences generally appear to be larger than the lacustrine deposits, a very large diatomite deposit reported in China appears to be lacustrine (Lu, 1998, p. 53). The oldest marine occurrences are believed to be of Cretaceous age, about 138 million to 66 million years ago; any older occurrences would presumably have been changed into other forms of silica. The oldest lacustrine deposits are believed to be 55 million to 38 million years old, of Eocene age. Many deposits worldwide, especially of the older marine type, have been found in uplifted coastal areas exposed to some volcanic effects (such as the Pacific Rim from Chile to Japan). Lacustrine deposits, especially in mountainous localities, also often show some association with volcanic activity (such as the Pacific Northwest). However, there are lacustrine environments where diatomite deposits are presently forming in lowlands far removed from volcanic activity (such as Florida).

Production

Recovery of diatomite from most deposits is by low-cost open pit mining because many occurrences are at or near the surface and the topography allows for open pit mining. To remove overburden and excavate ore, different combinations of rippers, dozers, scrapers, front-end loaders, power shovels, and dump trucks are used. Outside the United States, however, underground mining is fairly common (such as in Chile, China, and France) owing to deposit form and depth and topographic and other constraints. Usually, room and pillar methods are used, often with equipment similar to that used in open pits, but the smallest mines are excavated with hand tools. Explosives are not normally needed at surface or underground mines because of the rock's soft, friable nature. In Iceland, dredging is used to recover diatomaceous mud from the bottom of a lake. As climate permits, at many mines the ore is stockpiled in the open to segregate it by grade and to reduce the normally high moisture content before delivering it to the processing facility.

Diatomite processing is usually done near the mine to reduce the cost of hauling up to 65% water, but the cost of delivering energy (electric power and fuel) to the site is an offsetting consideration. Processing typically involves a series of crushing, drying, size reduction, and calcining operations, using heated air for conveying and classifying within the plant. Commonly, spiked rolls and hammer mills are used for primary crushing to a size of -1.25 centimeters (0.5 inches), while limiting damage to the diatomite structure. With the heated air and multiple passes through special "milling" fans and air cyclones, further drying, size reduction, and classifying are accomplished. The cyclones not only classify for size but also remove undesirable components in the raw feed based on density differences. Size reduction aims at separating individual frustules without destroying their delicate structure. Fines, especially from baghouses used to remove particulates from the cyclone discharge waste or recycle air, are used mostly for filler grade products, and the coarser bottom discharge particles are used for filter grades. In the latter stages of processing, calcining is normally done in rotary kilns to effect the physical and chemical changes previously mentioned. Plant operators take special precautions to overcome any free crystalline silica health hazards, particularly to the lungs, by containing dust within enclosures and requiring employees to use respirators. Although the generally high moisture in the ore reduces the free crystalline silica health hazards in mining areas, precautions are still taken.

Production cost allocations were reported for the United States in 1983 as 10% mining, 60% processing, and 30% packing and shipping; a 1990 report stated energy costs were 25% to 30% of direct costs (Breese, 1994, p. 405). The proportion of the product that is calcined directly affects energy consumption.

For the United States, the diatomite production data used to prepare table 1 were collected by a survey sent by the U.S. Geological Survey (USGS) to all known mine producers who voluntarily gave a 100% response as to the tonnage and value sold or used, which historically has been considered in these statistics as production. The survey for 2000 covered 7 diatomite-producing companies with 13 separate mining areas and 12 processing facilities in California, Nevada, Oregon, and Washington. Two of these operations were reported as inactive. Major producers were Celite Corp. (Lompoc, CA, and Quincy, WA); Eagle-Picher Industries Inc. (Lovelock and Fernley, NV, and Vale, OR); and Grefco Minerals, Inc. (Burney and Lompoc, CA, and Mina, NV). Smaller producers were Calveras Cement Co. (Burney, CA); CR Minerals Corp. (Fernley, NV); Moltan Co. (Fernley, NV); and Oil-Dry Production Co. (Christmas Valley, OR). California continued to be the leading producing State, followed by Nevada. The combined production of these two States accounted for about 87% of the U.S. production in 2000.

Consumption

Apparent domestic consumption (production sold or used based on USGS's survey plus imports minus exports using trade data furnished by the Department of Commerce; stock data are

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not available) of diatomite in 2000 was about 547,000 t, a 12% decrease from 625,000 t in 1999.

According to data from the USGS survey, total domestic and export quantities of filter-grade diatomite sold or used by U.S. producers was 446,000 t in 2000, 4% less than in 1999. For absorbents, the second largest category, 96,000 t was consumed, 21% less than in 1999. Filler applications accounted for 95,000 t, 17% more than in 1999, and insulation use increased by 20% to 18,000 t. Other consumption applications decreased by 69% to 21,000 t, special product sales and cement manufacturing constituting the majority of that amount (table 2). Comparing 2000 data with 1995 data for percentage of total use, filter use declined, filler use increased, insulation use remained the same, while absorbent and other uses (mostly special product sales and cement manufacture) increased slightly.

In antiquity, diatomite was used by the Greeks as an abrasive and in making lightweight building brick and blocks. In A.D. 535, blocks of diatomite were used for the 30-meter-diameter dome of the Church of St. Sophia in Istanbul, Turkey (Maurrasse, 1978). However, it only became of industrial interest in Western Europe in the mid-1800s. One of the first uses at that time was as cut blocks and bricks for heat-insulation. In the 1860s, pulverized diatomite became the preferred absorbent and stabilizer of nitroglycerine used by Alfred Nobel to make dynamite. The site of the first U.S. production of diatomite was in Maryland in 1884. By the late 1880s, the very pure, huge deposit near Lompoc became the focus of interest and has continued to dominate the world markets. Diatomite is now used principally as a filter aid; but it has many other applications, such as an absorbent for industrial spills and for pet litter, a filler in a variety of products from paints to dry chemicals, as an insulation material in sawn and molded shapes and as loose granules, a mild abrasive in polishes, and a silica additive in cement and various other compounds.

Commercial diatomite products provide fine-sized, irregular-shaped porous noncaking particles having a large surface area and a high liquid absorption capacity. They are chemically relatively inert, have a low refractive index, are mildly abrasive, have low thermal conductivity with a reasonably high fusion point, can be slightly pozzolanic, are very high in silica, and can be produced and delivered at a cost consistent with customers applications. Sawn shapes have long been used as lightweight building material (especially in 20th century China) and for insulation, primarily thermal (especially the high-clay-containing Danish moler), and continue to account for a significant part of world diatomite production. Dried natural products and calcined products are used in the aforementioned applications. Particulate products are more widely used and can be tailored to fit desired uses by blending various grades of calcined and natural material. The major use, in a great variety of grades, is as a filtration medium for beverages (especially beer and wine), sugar and sweetener liquors, oils and fats, petroleum and chemical processing (including waste drycleaning fluids), pharmaceuticals, and water (potable, industrial process, waste, and swimming pool). A large and growing application is use as an absorbent for industrial spills (oil and toxic liquids) and for pet litter. Another important broad category of use is as a filler, often serving a dual purpose such as an extender and flatting agent in paints and coatings, a bulking and anticaking agent in granular materials, a multieffect component in plastics (including preventing films from sticking), and an extender/absorbent carrier for dry pesticides, pharmaceuticals, catalysts, and other chemicals. Significant other products include an insulation material in bulk (loose), in molded shapes, and in calcium silicate; other insulation products as a component; and a silica additive in various compounds including mortar and portland cement where it is used also for its pozzolanic properties. Worldwide use, including moler, was estimated in 1993 to be almost 50% for filtration, more than 25% for fillers, 17% for insulation, and about 10% for absorption and other applications (Roskill Information Services Ltd., 1994, p. 3).

Commercial diatomite products are offered in a great variety of grades. Principal factors are the size, shape, overall arrangement and proportions of the various types of frustules (particularly the effect on filtration rate, product clarity, and absorption capacity), and content of silica and various impurities, such as certain minerals and chemicals (especially the form of iron, a major impurity), clay, sand, and organics. There are a number of additional specialized application specifications (brightness/whiteness and abrasive hardness). Free crystalline silica content, although normally low, is also required by some environmental regulations, particularly for calcined products. A major influence on the grade is the extent of processing within three broad classifications: naturally milled and dried; plain ("straight") calcined (to 1,000° C); and flux-calcined (to 1,200° C with the addition of up to 10% of sodium compounds, such as soda ash, salt, or sodium hydroxide). Calcining removes organics, increases filtration rate (surface area is reduced by fusing more delicate structures of particles and sintering them into small clusters resulting in larger particle size and increased pore size), oxidizes iron (changing the buff to gray colors common in crude ore feed to pink or white), increases specific gravity, and increases particle hardness; but also disadvantageously produces free silica. Flux-calcining significantly affects the physical and chemical properties and makes a white product. Most filter grades are calcined.

Prices

The calculated weighted average unit value of diatomite sold or used by U.S. producers during 2000, using USGS survey data, was $256 per metric ton f.o.b plant, an 8% increase compared with $238 per ton in 1999 (table 3). Concomitantly, the average value per ton for filter use was down about 11% from the 1999 value. The average values per ton in 2000 for filler use and absorbent use decreased by about 16% and 19%, respectively. Comparing unit values in 2000 with those in 1995, in current 2000 dollars, the calculated weighted average unit value has increased by $7 per ton from $249. The filter grade product price per metric ton in 2000 was $29 less than in 1995. The filler grade unit value in 2000 was $45 less than the $302 price in 1995. Data on other grades are insufficient for accurate comparisons, although unit values for insulation grades appear to have decreased, and unit values for absorbent grades appear to have increased.

Foreign Trade

Export and import data presented herein are from the U.S. Census Bureau and of limited accuracy because of producer-reported inconsistencies as well as lack of detail for the various

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materials specified in the 2000 Harmonized Tariff Schedule (HTS) of the United States issued by the U.S. International Trade Commission.

Exports of diatomite from the United States in 2000 were 131,467 t according to the census data, which accounted for about 19% of all grades of domestic production sold or used as shown in the USGS survey and were 7% greater than 1999 exports (table 4). The data are issued under code 2512 of the HTS, described as applying to natural and straight-calcined diatomite, but industry sources indicate that exports also include some flux-calcined material. Flux-calcined material, however, according to HTS explanatory notes issued by the World Customs Organization of which the United States is a signatory member, is included under another code (code 3802.90.20.00) where, unfortunately, it cannot be separately identified from activated clays. Similarly, heat-insulating mixtures and sawn and molded unfired shapes of diatomite are in an "other" data classification (code 6806.90.00.90) and are not exclusively identified as diatomite. Also, fired sawn and molded shapes of diatomite are covered in a separate category with data (code 6901) that are not exclusively diatomite.

Industry information indicates that actual total exports of diatomite products can be estimated as a minimum of 300,000 metric tons per year (t/yr), which is about 44% of domestic mine production sold or used in 2000 according to the USGS survey. Industry sources suggest that 75% or more of exports are flux-calcined with the balance being mostly natural or straight calcined grades and only a small portion being material described in codes 6806 and 6901 of the HTS.

Products were exported to 74 countries according to the U.S. Census Bureau data. Main export markets were Germany (32,472 t), Canada (19,625 t), Japan (11,892 t), Belgium (9,136 t), Australia (8,698 t), and the United Kingdom (5,351 t), making up slightly more than 66% of the total exports reported. Based on the available data, the average unit value of exported diatomite was $310 per ton free alongside ship, compared with $324 per ton in 1999 and $360 per ton in 1994. Because the data may not include all the higher value material, as discussed above, actual average unit values may be higher.

Import data available for diatomite show 529 t coming from five countries. In descending order, France provided 34%, followed by China with 30%, with the remainder coming from Italy, Spain, and Mexico.

World Review

China continued to show steady growth in diatomite production in 2000, averaging an increase of 7,500 t/yr since 1998. Japan's production remained essentially the same in 2000 as that of 1999. For 2000, world output was estimated to be 1.89 Mt, which was a decrease compared with 1999 and the lowest global tonnage since 1995 (table 5). Major producers in 2000 were the United States at 36%, followed by China at 18%, Japan with 10%, Denmark at about 10% (all moler products), some former Soviet Union countries and France, each with about 4%. Mexico, Spain, Peru, and the Republic of Korea, in decreasing order of production, were the next ranking producers.

Outlook

The diatomite market appears to remain mature and generally stable at the close of the 20th century. Industry representatives expect the next 5 years to be similar to the past 5 years; increased energy costs and possible global overcapacity, however, may represent impediments to future expansion. The past encroachments into filter applications by more advanced technology (ceramic, polymeric, and carbon membranes) apparently are not of major concern to producers, possibly because of cost factors. Disposal of diatomite waste, however, is a problem not fully resolved by recycling. Emerging markets for diatomite include use in biotechnology and pharmaceuticals and as a nontoxic insecticide (Crossley, 2000, p. 135). The problem of free crystalline silica associated with diatomite, particularly when calcined, continues to be of concern.

References Cited

Antonides, L.E., 1999, Diatomite: U.S. Geological Survey Mineral Commodity Summaries 1999, p. 60-61.

Breese, R.O.Y., 1994, Diatomite, *in* Carr, D.D., and others, eds., Industrial minerals and rocks (6th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., p. 397-412.

Crossley, Penny, 2000, Clarifying matters—World diatomite reviewed: Industrial Minerals, no. 390, March, p. 119-141.

Durham, D.L., 1973, Diatomite, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 191-195.

Industrial Minerals, 2001, California energy crisis affects mineral producers: Industrial Minerals, no. 402, March, p. 16-18.

Lu, Wen, 1998, Chinese industrial minerals: Surrey, UK, Industrial Minerals Information Ltd., 209 p.

Maurrasse, Florentin, 1978, Diatomite, *in* Fairbridge, R.W., and Bougeois, Joanne, eds., Encyclopedia of sedimentology: Stroudsburg, PA, Dowden, Hutchinson & Ross, Inc., p. 263-266.

Meisinger, A.C., 1985, Diatomite, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 249-254.

Roskill Information Services Ltd., 1994, Economics of diatomite 1994 (7th ed.): London, Roskill Information Services Ltd., 146 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Diatomite. Ch. in Mineral Commodity Summaries, annual.
Diatomite. Ch. in Minerals Yearbook, annual.
Diatomite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Diatomite. Ch. in Industrial Minerals and Rocks, SME, Littleton, CO, 1994.
Diatomite. Ch. in Industrial Minerals Handy Book II (P.W. Harben), Metal Bulletin plc, London, 1995.
Diatomite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Economics of Diatomite. Roskill Information Services Ltd., London, 1994.

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TABLE 1
DIATOMITE SOLD OR USED, BY PRODUCERS IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

	1999	2000
Domestic production (sales)	747	677
Value	$178,000	$173,000

1/ Data are rounded to no more than three significant digits.

TABLE 2
DIATOMITE SOLD OR USED, BY MAJOR USE 1/

(Percent of U.S. production by metric tons)

	1999	2000
Absorbents	16	14
Fillers	11	14
Filtration	62	66
Insulation	2	3
Other 2/	9	3

1/ Includes exports.
2/ Includes silicate admixtures (especially for cement and unspecified uses).

TABLE 3
AVERAGE ANNUAL VALUE PER METRIC TON OF DIATOMITE, BY MAJOR USE 1/

	1999	2000
Absorbents	$201.82	$162.09
Fillers	305.60	257.44
Filtration	270.52	240.14
Insulation	36.79	35.71
Other 2/	43.72	1197.16
Weighted average	238.12	256.09

1/ Based on unrounded data.
2/ Includes absorbents and silicate admixtures.

TABLE 4
U.S. EXPORTS OF DIATOMITE 1/ 2/

(Thousand metric tons and thousand dollars)

Year	Quantity	Value 3/
1999	123	39,700
2000	131	40,800

1/ Harmonized Tariff System (HTS) code 2512.00.00.00, natural and straight-calcined grades, but in practice probably includes an undetermined quantity of flux-calcined product HTS code 3806.90.20.00.
2/ Data are rounded to no more than three significant digits.
3/ Free-alongside-ship (f.a.s.) U.S. customs value.

Source: U.S. Census Bureau.

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TABLE 5
DIATOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria	4 e/	2 r/	2 r/	3 r/	3
Argentina e/	9 3/	9	10	9	9
Australia e/	11	11	20	20	20
Brazil (marketable) e/	14 3/	14	14	14	14
Chile	12	12	15	14 r/	15
China e/	300	330	335	340	350
Colombia e/	4	4	4	4	4
Costa Rica	2 r/ e/	1 r/	2 r/	2 r/ e/	2
Czech Republic	35	--	-- e/	--	--
Denmark e/ 4/	185	185	185	185 r/	185
France e/	85	80	80	80	75
Iceland e/	26 3/	25	25	26	26
Iran e/ 5/	(6/)	(6/)	1 r/	4 r/ 3/	5
Italy e/	25	25	25	25	25
Japan e/	194 3/	194	190	190	190
Kenya	(6/)	(6/)	(6/)	(6/)	(6/)
Korea, Republic of	70	54	38	30 r/	32
Macedonia e/	5	5	5	5	5
Mexico	52	59	67	72 r/ 3/	75
Peru e/	35	35	35	35	35
Poland	2	1	2	2	2
Portugal e/	2	2	2	2	2
Romania	57	24	30	30	30
Spain e/ 7/	34 3/	36	36	36	35
Thailand	2	(6/)	--	2 r/ 3/	(6/)
U.S.S.R., former e/ 8/	100	90	80	80	80
United States 9/	729 e/	773	725	747	677
Total	1,990 r/	1,970 r/	1,930 r/	1,960 r/	1,890

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown. Purity and moisture content are generally not reported or estimated.

2/ Table includes data available through March 8, 2001.

3/ Reported figure.

4/ Data represent "extracted moler" (reported cubic meters times 1.5). Contains about 30% clay.

5/ Data are for Iranian years beginning March 21 of that stated.

6/ Less than 1/2 unit.

7/ Includes tripoli.

8/ U.S.S.R. dissolved December 1991; however, information is inadequate to formulate reliable estimates for individual countries.

9/ Sold or used by producers.

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EXPLOSIVES

By Deborah A. Kramer

Domestic survey tables were prepared by Feri Naghdi, statistical assistant.

In 2000, U.S. explosives production was 2.57 million metric tons (Mt), a 21% increase from that of 1999; sales of explosives were reported in all States. Coal mining, with 67% of total consumption, continued to be the dominant use for explosives in the United States. Kentucky, Virginia, Wyoming, West Virginia, and Pennsylvania, in descending order, were the largest consuming States, with a combined total of 51% of U.S. sales.

Legislation and Government Programs

On October 13, the Committee for Fair Ammonium Nitrate Trade filed a petition with the U.S. International Trade Commission (ITC) alleging that ammonium nitrate from Ukraine was being sold in the United States at less than fair value. As a result, the ITC began an antidumping investigation of imports of ammonium nitrate from Ukraine and determined that there was a reasonable indication that the domestic industry was being injured (U.S. International Trade Commission, 2000, p. 1-19). The International Trade Administration (ITA) of the U.S. Department of Commerce began its investigation into the antidumping allegation in November and made a preliminary determination in March 2001. According to the ITA's investigation, the estimated dumping margin for J.S.C. "Concern" Stirol was 113.38% ad valorem. The Ukraine-wide rate, which was applicable to all other producers and exporters, was also 113.38%. The ITA also determined that critical circumstances existed. A final determination was set to be completed 105 days after the notice was published in the Federal Register (U.S. Department of Commerce, 2001).

The Bureau of Alcohol, Tobacco and Firearms (ATF) of the U.S. Department of the Treasury was considering amending its regulations to require licensed importers of explosive materials to place the same identification marks on imported explosive materials that are required on explosive materials that are manufactured in the United States. The Institute of Makers of Explosives (IME), who initiated the request, expressed concern that the unidentified explosives could pose a significant safety and security hazard. The ATF was requesting comments from the public regarding the proposed change; comments were due by January 12, 2001 (U.S. Bureau of Alcohol, Tobacco and Firearms, 2000).

Production

Sales of ammonium-nitrate-based explosives (blasting agents and oxidizers) were 2.53 Mt, a 21% increase from that of 1999, and accounted for 99% of U.S. industrial explosives sales. Production of permissibles declined, but production of other high explosives increased (table 1). Figure 1 shows how sales for consumption have changed since 1991.

Because of the sharp decrease in U.S. explosives production from 1998 to 1999, followed by a corresponding sharp increase from 1999 to 2000, the 1999 data appear to be anomalous. Because coal production is the principal driver of explosives consumption, the sharp changes in explosives sales in these years would be expected to be reflected by a corresponding change in coal production. This, however, was not the case. From 1998 to 1999, U.S. coal production declined by about 1.5%. This small decrease was not enough to cause a decline of 28% in explosives sales. This anomaly is particularly evident in the sales to Wyoming where explosives sales declined by 70% from 1998 to 1999, yet coal production in the State actually increased by 7%. These sharp drops in explosives sales from 1998 to 1999 were followed by sharp increases from 1999 to 2000, again without a corresponding change in coal production. This would indicate that there were significant reporting errors in 1999.

Companies contributing data to this report, including those that are not members of the IME, are as follows (nonmembers are denoted by an asterisk):

Accurate Energetic Systems LLC
Apache Nitrogen Products Inc. *
Austin Powder Co.
Baker Atlas International
Coastal Chem Inc. *
Daveyfire Inc.
Douglas Explosives Inc.
Dyno Nobel Inc.
El Dorado Chemical Co.
The Ensign-Bickford Co.
Explosives Technologies International Inc. (ETI)
D.C. Guelich Explosives Co.
General Dynamics OTS Hitech Inc.
Jet Research Center
LaRoche Industries Inc. *
Mining Services International Corp.
W.A. Murphy Inc.
Nelson Brothers Inc.
Nitram Inc. *
Nitrochem Corp.
Orica USA Inc.
Owen Oil Tools Inc.
PCS Nitrogen Corp. *
St. Lawrence Explosives Corp.
Schlumberger Perforating Center
Senex Explosives Inc.
Slurry Explosives Corp.
Vet's Explosives
Viking Explosives and Supply Co.

LaRoche Industries Inc. filed for chapter 11 bankruptcy in May. In August, LaRoche announced the sale of its ammonium nitrate facilities in Alabama, Illinois, Missouri, and Utah to Orica LLC, a unit of Orica Ltd., an international manufacturer and distributor of explosives. After the U.S. Bankruptcy Court in Delaware approved the sales, Orica then sold the Cherokee, AL, and Crystal City, MO, facilities to LSB Industries Inc.,

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which planned to operate these facilities under its El Dorado Chemical Co. subsidiary (Green Markets, 2000).

Dyno Nobel Inc. and Orica USA Inc. established a joint-venture manufacturing company, Geneva Nitrogen Inc., to operate the Geneva, UT, industrial-grade ammonium nitrate facility that Orica acquired from LaRoche Industries. Through the joint venture, both companies will own 50% of the plant, as well as one-half of the associated production volume of 100,000 metric tons per year (t/yr). Each company planned to market its 50% portion of the produced volume separately (Dyno Nobel ASA, November 2, 2000, Dyno Nobel forms US nitrogen plant jv, accessed February 6, 2001, via URL http://www.dynonobel.com/dninternet/home1.nsf).

In February, ICI Explosives USA Inc. sold its remaining ammonium nitrate production facilities in Joplin, MO, to Joplin Manufacturing Inc., which is a unit of Orica, for approximately $5.2 million. Orica was committed to purchasing the output of the plants for 4 years as part of the original international explosives acquisition from ICI plc in May 1998 (ICI plc, February 24, 2000, ICI sells US explosives plants to ORICA, accessed June 13, 2000, via URL http://www.ici.com/pressoffice).

Consumption

Coal mining, with 67% of total explosives consumption, remained the largest application for explosives in the United States. According to the U.S. Energy Information Administration of the U.S. Department of Energy (DOE), for the first time in 40 years, coal production declined for 2 years in a row and reached 976 Mt, about 2.3% less than that in 1999 (Fred Freme, 2001, U.S. coal supply and demand—2000 review, accessed June 1, 2001, at URL http://www.eia.doe.gov/fuelcoal.html). The production decline was attributed to a drawdown in stocks and a lack of excess production capacity at some mines.

Wyoming, West Virginia, and Kentucky, in descending order, led the Nation in coal production, accounting for 59% of the total, and were among the largest explosives-consuming States, accounting for 37% of total U.S. explosives sales.

Quarrying and nonmetal mining, the second-largest consuming industry, accounted for 14% of total explosives sales; metal mining, 9%; construction, 8%; and miscellaneous uses, 2% (table 2). Kentucky, Virginia, Wyoming, West Virginia, and Pennsylvania, in descending order, were the largest consuming States, with a combined total of 51% of U.S. sales (table 3).

The value of new construction increased by 1.7%, based on constant 1996 dollars (U.S. Census Bureau, 2001, Value of construction put in place, accessed June 20, 2001, at URL http://www.census.gov/prod/ 2001pubs/c30-0103.pdf). Federal Reserve Board indices indicated that the industry growth rate for metal mining from 1999 to 2000 was -4.2% and that the growth rate for stone and earth minerals was -1.8% (Federal Reserve Board, 2000, Industrial production and capacity utilization—Federal Reserve statistical release G17, accessed June 20, 2001, at URL http://www.federalreserve.gov/releases/G17/Revisions/20001205/table6.txt).

Classification of Industrial Explosives and Blasting Agents.—Apparent consumption of commercial explosives used for industrial purposes in this report is defined as sales as reported to the IME. Commercial explosives imported for industrial uses were included in sales.

The principal distinction between high explosives and blasting agents is their sensitivity to initiation. High explosives are cap sensitive, whereas blasting agents are not. Black powder sales were minor and were last reported in 1971. The production classifications used in this report are those adopted by the IME.

High Explosives.—Permissibles.—The Mine Safety and Health Administration approved grades by brand name as established by National Institute of Occupational Safety and Health testing.

Other High Explosives.—These include all high explosives except permissibles.

Blasting Agents and Oxidizers.—These include (1) ammonium nitrate-fuel oil (ANFO) mixtures, regardless of density; (2) slurries, water gels, or emulsions; (3) ANFO blends containing slurries, water gels, or emulsions; and (4) ammonium nitrate in prilled, grained, or liquor (water solution) form. Bulk and packaged forms of these materials are contained in this category. In 2000, about 93% of the total blasting agents and oxidizers was in bulk form.

World Review

Australia.—Dyno Nobel officially opened its Queensland Nitrates Pty. Ltd. facility in October. The $240 million complex has the capacity to produce 180,000 t/yr of ammonium nitrate. Much of the plant's output was expected to be marketed to the local coal-mining industry and to complement Dyno Nobel's other manufacturing facilities in the area—its explosives plant at Bajool and its detonator assembly facility at Helidon (Dyno Nobel ASA, October 6, 2000, Opening of Dyno Nobel AN complex, accessed February 6, 2001, at URL http://www.dynonobel.com/dninternet/home1.nsf).

Europe.—Orica announced that it would form a joint venture with Accept Corp. of Kazakhstan to manufacture and market explosives in Kazakhstan. The joint venture will be called Orica Kazakhstan, and Orica would own 80% of the company, and Accept, the remaining 20%. Orica Kazakhstan would be the first modern explosives manufacturer to be established in the country. The $100 million per year explosives requirements of Kazakhstan's mining industry have been supplied by imports, predominantly from Russia (Orica Ltd., May 18, 2000, Orica establishes Kazakhstan venture, accessed June 12, 2000, via URL http://www.orica.com/business/cor/wcor00009.nsf/webnav2/News+Releases?OpenDocument).

In October, Orica announced that it had signed a letter of intent to acquire the German firm Dynamit Nobel AG for about $38.2 million. The acquired business includes manufacturing sites at Troisdorf and Wurgendorf in Germany and Sirgala in Estonia. In addition, Dynamit Nobel is a major manufacturer of detonators for commercial explosives with production facilities at Troisdorf. The acquisition also would give Orica full ownership of Precision Blasting Systems GmbH, a joint venture formed in 1999 with Dynamit Nobel to develop and manufacture electronic detonator systems based on the combined technology of both companies (Orica Ltd., August 31, 2000, Orica planning European explosives acquisition, accessed February 6, 2001, via URL http://www.orica.com/business/cor/wcor00009.nsf/webnav2/News+Releases?OpenDocument).

Kimit AB and Orica signed a letter of intent to form a joint venture to manufacture, supply, and distribute commercial explosives in the Nordic countries. The joint venture was

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expected to have initial sales of approximately $3.6 million. Orica Europe Ltd. would hold 51% and Kimit would hold 49% of the shares of the new company (Orica Ltd., October 9, 2000, Orica and Kimit to form Scandinavian explosives venture, accessed March 13, 2001, via URL http://www.orica.com/business/cor/wcor00009.nsf/webnav2/News+Releases?OpenDocument).

South America.—Orica formed a joint-venture company with Merand Group in Venezuela in order to increase its participation in the Venezuelan explosives market. The joint-venture company was expected to operate under the name Orica Venezuela C.A. The new company signed an agreement with Compañía Anónima Venezolana de Industrias Militares (CAVIM), a state-owned company that regulates the manufacture of industrial explosives in Venezuela, to build and operate a plant to supply CAVIM with the bulk explosives needs of its customers for at least the next 5 years. Orica estimated that the Venezuelan market for industrial explosives has a value of about Australian $35 million and was expected to grow at around 10% per year (Orica Ltd., April 27, 2000, Orica forms new company in Venezuela, accessed June 12, 2000, via URL http://www.orica.com/business/cor/wcor00009.nsf/webnav2/News+Releases?OpenDocument). Orica's existing Latin American explosives interests in the Americas include manufacturing operations in Argentina, Brazil, Chile, and Mexico.

Current Research and Technology

After at least 20 years of efforts, scientists at the University of Chicago synthesized the compound octocubane ($C_8N_8O_{16}$). Octocubane consists of a cube of eight carbon atoms with nitro (NO_2) groups attached to each carbon atom. This material could be one of the most powerful explosives developed. It could be twice as powerful as trinitrotoluene (TNT), and it is thought to be 20% to 25% more energetic than High-Melting eXplosive (HMX), one of the most powerful military explosives in use today. Unlike these materials, however, octocubane is shock insensitive, which means it is much safer to handle. In addition, octocubane should burn into carbon dioxide and nitrogen, which, unlike some other explosive materials residues, should not harm the environment. Scientists at the Naval Research Laboratory are investigating the structural, electronic, and vibrational properties of octocubane (Wu, 2000).

The Defense Advanced Research Projects Agency developed a prototype system that can detect plastic landmines containing TNT in the field. The prototype is based on quadrupole resonance technology that uses an externally applied radio-frequency, magnetic-field pulse at a frequency that is specific to individual explosive compounds. When the pulse is aimed at the ground, it excites the molecules of any explosives present, generating a characteristic response that can be measured and analyzed by the system. In a test, the prototype detected all of the antipersonnel and antitank landmines with no false alarms. Based on these results, the U.S. Army and the U.S. Marine Corps were initiating programs to develop the system for field use (Defense Advanced Research Projects Agency, 2000).

Chemical Detection Technologies Inc. developed a new device that the company claimed could clear 500 to 2,000 square meters of land per hour of landmines, a process that can take 2 to 3 days with humans and trained dogs. The device uses low-energy x rays that make nitrates in the soil fluoresce; this fluorescence is captured by a specially designed germanium detector. The spectroscopic emission band of the nitrates is compared with the spectroscopic emissions of known explosives to determine its type. Although nitrates that are found naturally in the soil and nitrates from fertilizers will also fluoresce, their chemical signatures are different from those of the explosives in landmines, and the device should not be confused. The new device has been through preliminary field tests in Croatia, and the company planned to complete more testing (Photonics Spectra, 2000b).

The U.S. Navy was testing two new systems to accurately detect mines underwater. The two systems produce video images of mines at near television resolution in real time; one detects mines at or near the water's surface, the other detects mines on the bottom. The technology uses a laser, a streak-tube receiver (similar to a photomultiplier tube), and conventional digital recording technology. When the laser detects an image, it is captured by the streak tube and digitally recorded. Successive images are processed into a three-dimensional image. A human operator is still required to determine which image is that of a mine. Although the new technology is fast, offers higher resolution, and is more rugged than conventional mine-detection systems, it only covers a small area at a time. Because of this problem, the new technology will probably be used as an adjunct to traditional methods in specific trouble areas (Photonics Spectra, 2000a).

Through its Sandia National Laboratories, the DOE was undertaking several research projects on explosives technology. In one of the projects, Sandia was investigating methods of treating water saturated with organic explosives such as TNT and cyclotrimethylenetrinitramine (RDX), which is typical of water that would be generated at explosives-producing plants. The objective is for the treated water to meet U.S. Environmental Protection Agency requirements for discharge into sanitary sewers or to be able to be recycled for further use in processing explosives. Sandia scientists conducted a series of experiments that used different combinations of ultraviolet light, a catalyst (titanium dioxide in most cases), oxidants (hydrogen peroxide or ozone), and biodegradation (decomposition by bacteria). They applied these treatments in various combinations, studying the potential of photocatalysis both as a single-treatment process and as a pretreatment to biodegradation. The researchers found that when photocatalysis preceded biodegradation, both explosives decomposed to near-zero toxicity. Future work was projected to include optimizing the process variables and constructing a pilot plant (Sandia National Laboratories, [undated], Wastewater treatment, accessed June 15, 2001, at http://www.sandia.gov/explosive/projects/pinkwater.htm).

Also at Sandia, researchers are working with entomologists from the University of Montana to determine if foraging bees can be used to detect buried landmines. In many developing countries, thousands of acres of land lie unused because farmers are afraid to work their fields fearing buried landmines. As bees forage for nectar and pollen, they attract particles of dust, soil, and pollen to their bodies and bring samples back to the hive. In doing so, they provide a chemical survey of an area extending a mile or more from the hive in all directions. The research team is establishing two bee colonies in a remote test area that has many buried mock landmines. The colonies will live in highly instrumented "honeybee condos" that automatically count the number of times bees fly in and out of the hive, to track the bees flight activity. Pollen, dust, air, and other samples collected by the bees and brought to the hives

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will be analyzed for trace amounts of explosives. Two other control colonies will be established to provide baseline data for comparison. The entomology team has demonstrated that by providing a new bee colony with feeders tainted with a marker chemical, then gradually moving the feeders farther from the hive and eventually removing them, bees can be trained to forage wherever they smell the chemical. If bees can be trained to seek TNT, the team may attach small diodes onto the backs of several hundred TNT-trained bees. Then, using a handheld radar tracking device, they will chart where those bees go to determine whether they tend to forage near the locations of known landmines (Sandia National Laboratories, [undated], Sandia, University of Montana researchers try training bees to find buried landmines, accessed June 15, 2001, at URL http://www.sandia.gov/explosive/projects/minebees.htm).

Sandia is helping to develop a portable mine-detection system that incorporates ion mobility spectrometry, which is the same technology that is used to check airline passengers. This technology is expected to be capable of quickly detecting and classifying minute quantities of explosive molecules. The system incorporates a new Sandia-developed concentration technology that potentially can chemically amplify the source strength thousands of times. The project originally was directed at detecting sea mines and unexploded ordnance in shallow water and is sponsored jointly by the DOE and the Department of Defense (Sandia National Laboratories, [undated], Sandia Labs developing means to sniff out mines chemically and electronically, accessed June 15, 2001, at URL http://www.sandia.gov/explosive/projects/landmine.htm).

An instrument that can detect tiny explosions could lead to an inexpensive hand-held device to screen people and luggage at airports or to detect landmines. The device, being developed at the DOE's Oak Ridge National Laboratory, is based on miniature micromachined silicon cantilevers one-tenth the width of a human hair that can detect tiny forces caused by heat-induced nanoexplosions. The instrument, which has sensitivity in the parts-per-trillion range, works by absorbing TNT molecules given off by explosives. As the semiconductor material absorbs the TNT and is heated with power from a battery, the TNT molecules undergo tiny explosions that are detected by an optical beam. In addition, by scanning an appropriate temperature range, researchers can use this technology to detect many explosive molecules, including those used in plastic explosives (Oak Ridge National Laboratory, February 21, 2000, ORNL technology detects explosives with mini-explosions, accessed June 15, 2001, at URL http://www.ornl.gov/Press_Releases/archive/mr20000221-00.html).

Outlook

The DOE projects a 4.5% increase in coal production in 2001 and a 1.4% increase in production in 2002. Almost all of the production increase is projected to come from the western region. A decrease in production is projected to occur in the interior region, and a small increase in production is projected in the Appalachian region for 2001 and 2002 (U.S. Energy Information Administration, May 2001, Short-term energy outlook, accessed June 20, 2001, at URL http://www.eia.doe.gov/pub/forecasting/steo/oldsteos/may01.pdf). If these projections are correct, explosives consumption should increase in 2001 and then remain about the same in 2002. Because most of the increase in coal production is forecast for the western region, explosives consumption is not expected to increase at the same pace as coal production; the lower overburden-to-matrix ratio in the western region will lead to a slower growth in explosives consumption. Aberrations in weather patterns, however, could have a substantial impact on U.S. coal demand, because most of it is used for electricity production. Changes in coal demand obviously will have an impact on the explosives demand in the United States.

In the construction and quarrying sectors, a gradual increase in demand for construction aggregates is anticipated on the basis of the expected volume of work on the U.S. infrastructure that will be financed by the new Transportation Equity Act for the 21st Century.

References Cited

Defense Advanced Research Projects Agency, 2000, Prototype system successfully detects plastic TNT landmines: Arlington, VA, Defense Advanced Projects Research Agency news release, February 21, 2 p.

Green Markets, 2000, LaRoche-Orica-Eldorado deal closes; Dyno Orica forge jv on Geneva AN plant: Green Markets, v. 24, no. 45, November 6, p. 1, 12.

Photonics Spectra, 2000a, Photonic minesweeping: Photonics Spectra, v. 34, no. 11, November, p. 84-85.

———2000b, X-rays mark the spot for mines: Photonics Spectra, v. 34, no. 11, November, p. 28-29.

U.S. Bureau of Alcohol, Tobacco and Firearms, 2000, Identification markings placed on imported explosive materials (2000R-238P): Federal Register, v. 65, no. 219, November 13, p. 67669-67670.

U.S. Department of Commerce, 2001, Notice of preliminary determination of sales at less than fair value and postponement of final determination—Solid agricultural grade ammonium nitrate from Ukraine: Federal Register, v. 66, no. 43, March 5, p. 13286-13292.

U.S. International Trade Commission, 2000, Certain ammonium nitrate from Ukraine—Investigation no. 731-TA-894 (preliminary): U.S. International Trade Commission, USITC publication no. 3374, December, 19 p.

Wu, C., 2000, Powerful explosive blasts onto scene: Science News, v. 157, no. 4, January 22, p. 54.

TABLE 1
SALIENT STATISTICS OF INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES 1/

(Metric tons)

Class	1999	2000
Permissibles	1,800	1,530
Other high explosives	31,100	33,900
Blasting agents and oxidizers	2,090,000	2,530,000
Total	2,120,000	2,570,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Institute of Makers of Explosives.

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TABLE 2
ESTIMATED INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY CLASS AND USE 1/ 2/

(Thousand metric tons)

Class	Coal mining	Quarrying and nonmetal mining	Metal mining	Construction work	All other purposes	Total
1999:						
Permissibles	2	(3/)	(3/)	(3/)	--	2
Other high explosives	4	14	1	11	1	31
Blasting agents and oxidizers	1,400	277	202	147	58	2,090
Total	1,410	291	203	157	59	2,120
2000:						
Permissibles	2	(3/)	(3/)	(3/)	--	2
Other high explosives	4	15	1	12	1	34
Blasting agents and oxidizers	1,720	332	235	182	70	2,530
Total	1,720	347	236	194	71	2,570

-- Zero.
1/ Distribution of industrial explosives and blasting agents by consuming industry estimated from indices of industrial production and economies as reported by the U.S. Department of Energy, the Federal Reserve Board, the U.S. Department of Transportation, and the U.S. Census Bureau.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

TABLE 3
INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY STATE AND CLASS 1/

(Metric tons)

	Class							
	1999				2000			
	Fixed high explosives				Fixed high explosives			
State	Permissibles	Other high explosives	Blasting agents and oxidizers	Total	Permissibles	Other high explosives	Blasting agents and oxidizers	Total
Alabama	43	823	91,600	92,500	33	603	59,400	60,000
Alaska	--	32	3,770	3,800	--	50	12,100	12,200
Arizona	--	414	109,000	109,000	20	548	112,000	112,000
Arkansas	--	180	8,010	8,190	--	201	11,200	11,400
California	5	720	33,700	34,400	(2/)	522	41,600	42,100
Colorado	103	2,310	40,900	43,300	58	3,070	71,600	74,700
Connecticut	--	1,990	8,000	9,990	--	1,580	17,700	19,200
Delaware	--	2	96	98	--	--	81	81
Florida	--	224	8,740	8,970	--	235	16,800	17,000
Georgia	--	685	41,700	42,400	--	806	57,000	57,900
Hawaii	--	9	1,140	1,150	--	11	1,320	1,330
Idaho	21	462	7,590	8,070	11	535	12,800	13,400
Illinois	--	2,000	43,500	45,500	--	1,650	42,300	44,000
Indiana	1	381	33,900	34,200	9	546	37,900	38,400
Iowa	--	744	17,300	18,100	--	923	16,700	17,700
Kansas	--	303	16,900	17,200	--	440	18,900	19,300
Kentucky	975	2,460	408,000	411,000	806	2,720	499,000	502,000
Louisiana	--	136	2,040	2,180	--	131	2,000	2,130
Maine	--	146	517	663	--	20	270	290
Maryland 3/	(2/)	95	4,770	4,870	2	103	5,430	5,540
Massachusetts	--	403	2,390	2,790	--	418	3,450	3,870
Michigan	--	59	9,930	9,990	--	265	10,100	10,300
Minnesota	--	142	45,200	45,400	(2/)	204	63,700	63,900
Mississippi	--	407	6,640	7,050	--	22	1,400	1,420
Missouri	2	1,490	45,500	47,000	2	1,280	116,000	117,000
Montana	19	119	29,400	29,500	19	145	21,100	21,200
Nebraska	--	90	1,770	1,860	--	121	1,860	1,980
Nevada	4	1,300	124,000	125,000	4	1,710	75,300	77,000
New Hampshire	--	598	5,190	5,790	--	439	5,720	6,160
New Jersey	--	171	6,280	6,450	--	150	5,890	6,040
New Mexico	--	123	33,900	34,000	2	233	36,200	36,400
New York	3	605	11,800	12,400	1	825	13,500	14,400
North Carolina	--	1,320	44,800	46,100	--	1,560	52,500	54,100
North Dakota	--	6	1,860	1,860	--	9	601	610

See footnotes at end of table.

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TABLE 3--Continued
INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY STATE AND CLASS 1/

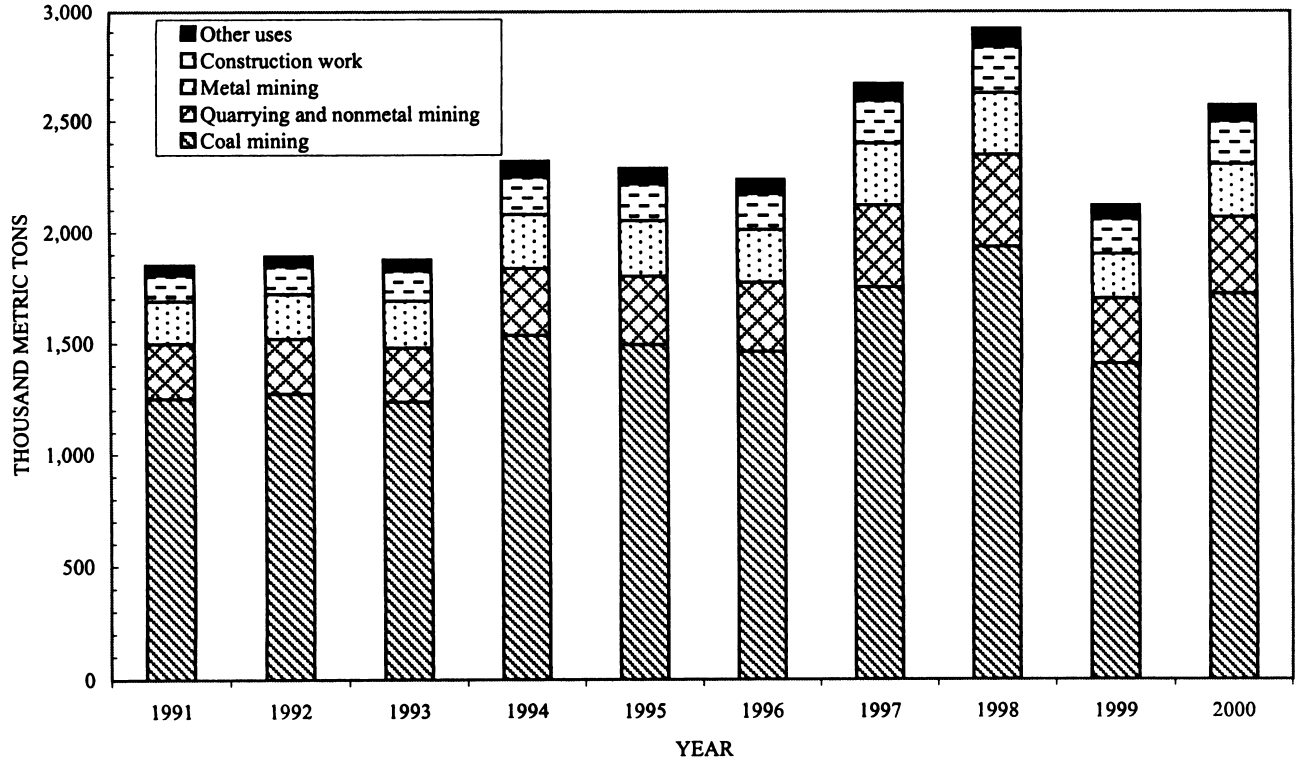
(Metric tons)

	Class							
	1999				2000			
	Fixed high explosives				Fixed high explosives			
State	Permissibles	Other high explosives	Blasting agents and oxidizers	Total	Permissibles	Other high explosives	Blasting agents and oxidizers	Total
Ohio	5	477	69,800	70,300	6	539	74,100	74,600
Oklahoma	1	202	20,300	20,500	1	249	17,900	18,100
Oregon	--	180	5,280	5,460	--	142	4,980	5,120
Pennsylvania	98	3,280	110,000	114,000	88	1,980	139,000	141,000
Rhode Island	--	17	80	96	--	20	568	589
South Carolina	--	126	9,070	9,200	--	174	11,200	11,300
South Dakota	--	33	3,370	3,400	--	12	1,010	1,020
Tennessee	3	730	45,500	46,300	3	1,460	48,600	50,100
Texas	(2/)	420	28,400	28,800	3	716	39,000	39,700
Utah	138	764	33,800	34,700	87	385	50,900	51,300
Vermont	6	39	518	562	8	35	238	281
Virginia	250	1,700	194,000	196,000	206	2,690	231,000	234,000
Washington	--	1,030	10,700	11,700	--	1,110	14,600	15,700
West Virginia	121	609	214,000	214,000	117	1,240	220,000	221,000
Wisconsin	--	320	11,000	11,300	--	503	15,400	15,900
Wyoming	4	233	81,400	81,700	44	635	223,000	224,000
Total	1,800	31,100	2,090,000	2,120,000	1,530	33,900	2,530,000	2,570,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes the District of Columbia.

Source: Institute of Makers of Explosives.

FIGURE 1
SALES FOR CONSUMPTION OF U.S. INDUSTRIAL EXPLOSIVES



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FELDSPAR AND NEPHELINE SYENITE

By Michael J. Potter

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Feldspar was used in commerce in the form of aluminosilicates that contained calcium, potassium, and sodium. Nepheline syenite, which is a light-colored, silica-deficient feldspathic rock made up mostly of sodium and potassium feldspars and nepheline, was not mined in the United States but was imported from Canada for use in the glass and ceramic industries.

Feldspar

In glassmaking, alumina from feldspar improves product hardness, durability, and resistance to chemical corrosion. In ceramics, feldspar is used as a flux, lowering the vitrifying temperature of a ceramic body during firing and forming a glassy phase.

In 2000, U.S. shipments (domestic sales) of glass containers, a major end use of feldspar, were about 3% less than in 1999 (U.S. Census Bureau, February 2001, Glass containers—Current industrial reports, accessed April 23, 2001, at URL http://www.census.gov/cir/www/m32g.html). In the housing and remodeling markets, feldspar was used in glass fiber insulation, sanitaryware, and tile. Housing starts were an estimated 1.59 million, which was about 4% less than in 1999 (U.S. Census Bureau, January 18, 2001, Housing starts and building permits in December 2000, accessed May 4, 2001, at URL http://www.census.gov/const/C20/c20_0012.txt).

Ceramic tile consumption (including imports) in the United States increased each year during the 1990s to 206.9 million square meters (Mm^2) in 1999 from 85.1 Mm^2 in 1991. Imports accounted for approximately 67% of the tile consumed in the United States in 1999 (Daniels, 2000).

Production.—In 2000, U.S. production of marketable feldspar was an estimated 790,000 metric tons (t) with a value of $44.5 million (table 1). Feldspar was mined in seven States, which were, in descending order of output, North Carolina, Virginia, California, Georgia, Oklahoma, Idaho, and South Dakota. North Carolina accounted for about 44% of the total. Mining was by 9 companies with a total of 12 plant operations—4 in North Carolina, 3 in California, and 1 in each of the remaining States listed above.

Domestic production data for feldspar were collected by the U.S. Geological Survey by means of a voluntary survey. Of the 12 known plant operations, 6 responded by the data closeout date. The six operations represented about 60% of the year 2000 production shown in tables 1 and 2. Data for the remaining six operations were estimated from prior year production levels.

Oglebay Norton Co. acquired the mica operations of Franklin Industrial Minerals, located in New Mexico and North Carolina. The North Carolina site also produced feldspathic sand, kaolin, quartz sand, and potassium feldspar. The operations were incorporated under a wholly owned subsidiary, Oglebay Norton Specialty Minerals, Inc. (North American Minerals News, 2000).

Consumption.—Of the U.S. feldspar sold or used, 66% went into the manufacture of glass, including glass containers and glass fiber. Pottery (including electrical insulators, sanitaryware, tableware, and tile) and other uses, such as fillers,

Feldspar and Nepheline Syenite in the 20th Century

In 1900, U.S. feldspar production was about 22,500 metric tons with a value of about $181,000. Quantitative end-use data were not available for that year, but uses were reported to be floor and wall tiles, glass, pottery, scouring soaps, and wood fillers. Feldspar was produced by selective mining and hand sorting of coarse-grained pegmatites from deposits located in Connecticut, Maine, New York, and Pennsylvania. Material was processed by dry crushing and grinding. Around 1910, uses for feldspar included enamelware, true porcelain, vitrified sanitaryware, and whiteware. Feldspar was used in both ceramic bodies and glazes. A major development in processing technology was the flotation process developed in 1939 in a cooperative effort between the U.S. Bureau of Mines and the feldspar industry. This process enabled treatment of a broader range of ores in which feldspar was more intermixed with quartz, mica, and other accessory minerals. The first commercial flotation plant began operation in North Carolina in 1946.

Nepheline syenite, mined in Ontario, Canada, is a feldspathic rock that, when processed, competes with feldspar in glass, pottery, and filler use. Official recording of U.S. imports of nepheline syenite began in 1939, when about 26,500 tons were imported. U.S. imports of nepheline syenite reached a high of about 497,000 tons in 1978.

In 2000, U.S. feldspar production was 790,000 tons. End uses were glass (66%) and pottery and other uses (34%). Feldspar use in glass containers faced competition from recycled glass, metal, paper, and plastic containers. Imports of nepheline syenite were 356,000 tons. Total world production of feldspar in 2000 was about 9 million tons. Italy produced 2.6 million tons; Turkey, 1.1 million tons; and France, 600,000 tons. Output came from at least 46 other countries.

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accounted for the remaining 34% (table 4). Tableware included plates, mugs, cups, and saucers and was categorized in the trade based on the contained proportions of clay, kaolin, quartz, and feldspar and on the firing process. Earthenware, the most common form of tableware and originally considered to be the cheapest form, has been offered in highly decorated versions with a more upscale image. Stoneware is earthenware given more strength by being fired at high temperature. It is nonporous and commands a higher price. Porcelain is semitransparent earthenware made by combining white china clay with either powdered glass or other hard materials. Bone china is a combination of porcelain and bone ash; fine bone china is an even thinner version (Selzer, 2000).

Prices.—The prices for ceramic grade sodium feldspar, 170-250 mesh, ex-works United States, increased at yearend 2000 by about $3 per ton at both lower and upper ends of the price range to about $67 to $80 per ton. This increase in not reflected in table 5. Ceramic grade feldspar, 200 mesh, bagged, ex-works Eastern United States, increased by about $7 per ton compared with the price earlier in the year to about $139 per ton; this was also a $34 increase per ton compared with the price in December 1999. Glass grade feldspar, 30 mesh, bulk, ex-works Eastern United States, increased by about $8 per ton at the upper end of its range to $57 per ton (not listed in table 5) (Mineral Price Watch, 2001).

World Review.—**Europe.**—After 1989-90, inexpensive natural gas was no longer available to ceramic factories in Eastern Europe from the former Soviet Union. With credit from Western European kiln manufacturers, a number of shuttle and tunnel kilns were put into service in Eastern and Central Europe during the mid-1990s. Private housing development in Eastern and Central Europe required large quantities of building materials, including sanitaryware, ceramic tiles, and roofing tiles. Western sanitaryware manufacturers began investing in some of the ceramic plants and brought marketing expertise. The quality of the sanitaryware and tile improved significantly, and most local producers were exporting at least 50% of their output (MacQuaid, 2000).

Mexico.—Housing construction was reported to consist of 370,000 to 380,000 units per year. The sanitaryware, or vitreous china, market in Mexico amounted to about 5.5 million units per year, including wash basins and other bathroom fixtures and accessories. Remodeling was another significant outlet for these items. Mexico exported about 70% of its sanitaryware production to the United States. A typical liquid slurry feed material (slip) for sanitaryware consisted of 22% to 27% ball clay, 26% to 35% kaolin, 22% to 32% silica, and 18% to 27% feldspar. The kaolin and ball clay were imported primarily from the United States; in Mexico, exploration for industrial minerals was still in the early stages (Harris, 2000).

Spain.—Feldspar output in 2000 was an estimated 425,000 t (table 8). End usage was 64% in ceramics, such as glazes, porcelain, sanitaryware, and tiles; 32% in glass; and 2% in other applications, such as paints, plastics, and rubber. Feldspar imports were about 350,000 metric tons per year (t/yr), of which 250,000 t/yr was sodium feldspar from Turkey (Regueiro y Gonzalez-Barros and Marchan Sanz, 2000).

Among Spain's largest feldspar producers were Industrias del Cuarzo SA, with output of 125,000 t/yr of potassium feldspar and 60,000 t/yr of feldspathic sands from its eolian (wind deposited) sands operation at Carrascal del Rio, Segovia; Compania Minera de Rio Piron, with around 100,000 t/yr of potassium feldspar from eolian sand deposits at its operation in Navas del Oro, Segovia; Llansa SA, producing about 80,000 t/yr of potassium/sodium and sodium feldspar from a pegmatite deposit in Llansa, Girona; and Basazuri SL, with 80,000 t/yr of albite in Lugo Province. Spain's reserves of feldspathic sands were said to be the largest in Europe (Regueiro y Gonzalez-Barros and Marchan Sanz, 2000).

Outlook.—According to Market Studies, Inc., Raleigh, NC, the dollar volume of the U.S. dinnerware market in 1998 was $1.4 billion. Demand for semivitreous china dinnerware increased by 7% in 1998, while that of vitreous china increased by 5.2%. Sales of semivitreous china were about 54% of the market, or $729 million. Continued growth in sales for the semivitreous category was projected to increase at a rate of 4.5% per year through 2003, reaching $910 million by 2003. Market Studies also projected that overseas demand for vitreous china dinnerware would remain unchanged through 2003. However, demand for U.S. semivitreous china dinnerware exports could increase at a rate of 5.7% per year, reaching $30 million by 2003 (Ceramic Industry, 1999).

The Cleveland, OH, market research company The Freedonia Group, Inc., projected U.S. demand for glass containers wold grow more slowly than for plastic containers in the near term. The Freedonia study also projected that the market for glass bottles should improve somewhat because their replacement in the soft drink and milk markets largely has been completed, that there would be a decline in loss of market share to plastics in bottled water and distilled spirits, and that metal cans would continue to account for about one-half of the beverage container market in unit terms (Ceramic Industry, 2000).

Consumption of container glass was showing growth in the beer and soft drink markets in such areas as China and Southeast Asia. On a worldwide basis, however, the ceramic industry was projected to show stronger growth than glass containers (Roskill Information Services Ltd., 1999, p. 4).

Nepheline Syenite

In glass and ceramics, nepheline syenite, like feldspar, provides alkalis that act as a flux to lower the melting temperature of a glass or ceramic mixture, prompting faster melting and fuel savings. In glass, nepheline syenite also supplies alumina, which gives increased resistance to scratching and breaking, improved thermal endurance, and increased chemical durability.

Canada and Norway produced nepheline syenite for glass and ceramic use. In Ontario, Canada, Unimin Canada, Ltd., operated two plants at its Blue Mountain deposit, about 175 kilometers northeast of Toronto. Output was about 617,000 t in 1998. An estimated 70% of the output went into glass, especially container glass and glass fiber. About 15% was used in ceramic applications and 15% in pigments and fillers (Guillet, 1994, p. 724). An estimated 60% of the output was shipped to the United States, 20% to the Canadian market, and 20% to European countries (Bolger, 1995, p. 31).

In Norway, North Cape Minerals AS produced about

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320,000 t of nepheline syenite in 1998 from an underground mine on the Arctic island of Stjernoya. An estimated 70% of the output went to glass manufacturing, 28% to ceramics, and 2% to filler (Bolger, 1995, p. 38).

In the European Union, the glass container recycling rate was more than 50% of glass container consumption. The growing trend to use recycled glass in glass manufacture was reducing the demand for nepheline syenite and feldspar. The increasing use of alternative packaging containers made of such materials as aluminum, coated paper, and plastic also was having an adverse effect on glass container consumption (Saller, 1999).

References Cited

Bolger, R.B., 1995, Feldspar and nepheline syenite: Industrial Minerals, no. 332, May, p. 25-45.

Ceramic Industry, 1999, Imports gain ground in U.S. dinnerware market: Ceramic Industry, v. 149, no. 9, August, p. 38-39.

Ceramic Industry, 2000, Flat glass markets remain strong—Container market dominated by plastics: Ceramic Industry, v. 150, no. 9, August, p. 51-52.

Daniels, R.E., 2000, Tile market continues growth despite anticipated slowdowns: Ceramic Industry, v. 150, no. 9, August, p. 32-35.

Guillet, G.R., 2000, Nepheline syenite, *in* Carr, D.D., and others, eds., Industrial minerals and rocks, 6th ed.: Littleton, CO, Society for Mining, Metallurgy, and Exploration, 1994, p. 711-730.

Harris, Paul, 2000, Mexican sanitaryware—Sitting pretty?: Industrial Minerals, no. 397, October, p. 87-99.

MacQuaid, P.J., 2000, Navigating historical opportunities in Eastern Europe: Ceramic Industry, v. 150, no. 9, August, p. 38-40.

Mineral Price Watch, 2001, Price increase for U.S. feldspar: Mineral Price Watch, no. 73, January, p. 6.

North American Minerals News, 2000, Oglebay Norton buys Franklin Industries' mica business: North American Minerals News, no. 56, January, p. 4.

Regueiro y Gonzalez-Barros, Manuel, and Marchan Sanz, Carmen, 2000, Industrial minerals of Spain: Industrial Minerals, no. 394, July, p. 53-65.

Roskill Information Services Ltd., 1999, The economics of feldspar: London, Roskill Information Services Ltd., 214 p. plus appendices.

Saller, Marcus, 1999, In a state of flux—Feldspar and nepheline syenite reviewed: Industrial Minerals, no. 385, October, p. 43-53.

Selzer, Sarah, 2000, Keeping the plates spinning—A European tableware focus: Industrial Minerals, no. 397, October, p. 77-85.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Feldspar. Ch. in Mineral Commodity Summaries, annual.

Feldspar. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Silica. Ch. in Minerals Yearbook, v. I, Metals and Minerals, annual. (For 1995 and previous years, included under Industrial Sand and Gravel chapter.)

Soda Ash. Ch. in Minerals Yearbook, v. I, Metals and Minerals, annual.

Other

Beverage Containers. The Freedonia Group, Inc., 1999.

Feldspar. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, 6th ed., Donald Carr, ed., 1994.

Feldspar. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

The U.S. Dinnerware Market. Market Studies, Inc., 1999-2000 ed.

TABLE 1
SALIENT FELDSPAR AND NEPHELINE SYENITE STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Feldspar:						
Produced e/ 2/	metric tons	890,000 3/	900,000	820,000	875,000	790,000
Value e/	thousands	$39,400	$42,500	$40,800	$42,700	$44,500
Exports 4/	metric tons	10,200	7,220	13,200	9,880	11,400
Value 4/	thousands	$1,390	$993	$1,430	$1,160	$1,490
Imports for consumption 4/	metric tons	7,150	8,580	6,560	6,840	7,220
Value 4/	thousands	$594	$753	$601	$757	$726
Nepheline syenite:						
Imports for consumption 4/	metric tons	247,000	346,000	320,000	311,000	356,000
Value 4/	thousands	$20,900	$23,900	$24,100	$23,200	$24,800
Consumption, apparent (feldspar plus nepheline syenite) e/ 5/	thousand metric tons	1,130	1,250	1,130	1,180	1,140
World, production (feldspar)	do.	8,290 r/	8,550	8,950 r/	8,910 r/	9,280 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Includes hand-cobbed feldspar, flotation-concentrate feldspar, feldspar in feldspar-quartz mixtures, and aplite.

3/ Reported figure.

4/ Source: U.S. Census Bureau

5/ Production plus imports minus exports.

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TABLE 2
ESTIMATED FELDSPAR PRODUCTION IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

Year	Flotation concentrate		Other 2/		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1999	408	19,200	467	23,500	875	42,700
2000	335	20,500	455	24,000	790	44,500

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes hand-cobbed, feldspar-quartz mixtures (feldspar content), and aplite.

TABLE 3
PRODUCERS OF FELDSPAR AND FELDSPATHIC MATERIALS IN 2000

Company	Plant location	Product
APAC Arkansas Inc.	Muskogee, OK	Feldspar-quartz mixture.
The Feldspar Corp.	Monticello, GA	Potassium feldspar.
Do.	Spruce Pine, NC	Sodium-potassium feldspar; feldspar-quartz mixture.
PW Gillibrand Co.	Simi Valley, CA	Feldspar-quartz mixture.
Granite Rock Co.	Felton, CA	Do.
KT Feldspar Corp.	Spruce Pine, NC	Sodium-potassium feldspar; feldspar-quartz mixture.
Oglebay Norton Specialty Minerals Inc.	Kings Mountain, NC	Feldspar-quartz mixture.
Pacer Corp.	Custer, SD	Potassium feldspar.
Unimin Corp.	Byron, CA	Feldspar-quartz mixture.
Do.	Emmett, ID	Do.
Do.	Spruce Pine, NC	Sodium-potassium feldspar.
U.S. Silica Co.	Montpelier, VA	Aplite.

TABLE 4
ESTIMATED FELDSPAR SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	1999		2000	
	Quantity	Value	Quantity	Value
Glass 3/	598	31,400	519	26,700
Pottery and miscellaneous	277	19,200	271	19,200
Total	875	50,600	790	46,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes hand-cobbed feldspar, flotation-concentrate feldspar, feldspar in feldspar-quartz mixtures, and aplite.
3/ Includes container glass, glass fiber, and other glass.

TABLE 5
PRICES FOR U.S. FELDSPAR, YEAREND 2000

(Dollars per metric ton)

	Price 1/
Glass grade:	
30 mesh, soda	44-50
80 mesh, potash	94-99
Ceramic grade:	
170 to 250 mesh, soda	64-77
200 mesh, potash	137

1/ Bulk, ex-works, United States.

Source: Industrial Minerals, no. 399, December 2000, p. 74.

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TABLE 6
U.S. EXPORTS OF FELDSPAR, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value	Quantity (metric tons)	Value
Canada	1,750	$241,000	1,610	$213,000
Costa Rica	907	125,000	1,500	210,000
Dominican Republic	227	27,100	312	60,000
India	--	--	378	40,000
Italy	5,140	457,000	5,720	598,000
Malaysia	120	31,000	82	27,000
Mexico	663	130,000	533	84,400
Nicaragua	396	46,300	817	113,000
Panama	152	15,000	--	--
Thailand	100	20,000	2	8,400
Venezuela	263	30,300	174	37,000
Other	164 r/	39,500 r/	261	99,000
Total	9,880	1,160,000	11,400	1,490,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF FELDSPAR, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value 2/	Quantity (metric tons)	Value 2/
Mexico	6,190	$549,000	7,080	$636,000
Other	646 r/	208,000 r/	132	89,700
Total	6,840	757,000	7,220	726,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.

Source: U.S. Census Bureau.

TABLE 8
FELDSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Algeria e/	7,000	7,000	7,000	2,820 r/	3,000
Argentina	72,539	105,320	42,468 r/	62,926 r/	61,000
Australia e/	17,000	20,000	20,000	20,000	20,000
Brazil (crude)	276,621	225,000	200,000 r/	220,000 r/	240,000 4/
Burma 5/	13,295	11,960	12,000 e/	12,000 e/	12,000
Chile	3,702	3,808	1,460	1,500 e/	1,500
Colombia	78,093	66,845	55,000 e/	55,000 e/	55,000
Ecuador	10,321	60,328	60,000 e/	50,000 e/	55,000
Egypt	53,783	57,335 r/	325,654	330 r/ e/	330,000
Finland e/	40,265 4/	40,000	40,000	40,000	40,000
France	546,000	621,000	600,000 e/	600,000 e/	600,000
Germany	359,666	455,969	450,000 e/	460,000 e/	460,000
Greece e/	60,000	65,000	65,000	65,000	60,000
Guatemala e/	11,060 r/	11,000 r/	11,000 r/	11,000 r/	11,000
India	85,213	95,455	104,509	105,000 e/	110,000
Iran	106,000 e/	125,000	185,709 r/	239,779 r/	240,000
Italy	2,310,000	2,300,000 e/	2,748,000	2,600,000 e/	2,600,000

See footnotes at end of table.

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TABLE 8--Continued
FELDSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Japan e/ 6/	55,122 4/	55,000	50,000	52,000	52,000
Kenya e/	100	100	100	100	100
Korea, Republic of	319,112	341,018	248,493	250,000 e/	250,000
Macedonia e/	15,000	10,000	10,000	10,000	10,000
Mexico	139,972	155,760	197,866	262,241 r/	334,439 4/
Morocco	12,659	15,110	5,616	5,000 e/	5,000
Nigeria e/	800 4/	1,000	500	500	600
Norway e/ 7/	76,000 r/	75,000	75,000	75,000	75,000
Pakistan	32,572	25,169	31,191	32,000 e/	32,000
Peru	5,900 r/	2,500 r/	4,000 r/	1,600 r/	5,600 4/
Philippines e/	40,000	30,000	30,000	25,000	25,000
Poland	64,000	73,800 r/	26,500 r/	50,000 r/ e/	50,000
Portugal	98,596	121,380	120,000 e/	120,000 e/	120,000
Romania	34,975	25,962	37,010 r/	36,635 r/	35,000
Russia e/	45,000	45,000	40,000	45,000	45,000
Serbia and Montenegro	4,801	4,880	4,280 r/	3,453 r/	3,000
South Africa	53,644	59,688	56,761	58,986	66,774 4/
Spain 8/	415,189	398,000	430,000	425,000 e/	425,000
Sri Lanka	11,200	25,700 r/	25,274 r/	26,012 r/	26,500
Sweden e/	45,000	50,000	45,000 r/	45,000	45,000
Taiwan	20	--	--	-- e/	--
Thailand	684,983	611,789	440,288 r/	626,415 r/	542,991 4/
Turkey	910,814	1,011,542	1,089,483	1,100,000 e/	1,200,000
United Kingdom (china stone) e/	8,000	8,000	8,000	8,000	8,000
United States e/	890,000 4/	900,000	820,000	875,000	790,000
Uruguay	2,100 r/	3,229	2,940	1,556 r/	1,600
Uzbekistan e/	70,000	70,000	70,000	70,000	70,000
Venezuela	205,000	160,000	148,000 r/	156,000 r/	160,000
Zimbabwe	3,248	2,254	2,241	2,250 e/	2,250
Total	8,290,000 r/	8,550,000	8,950,000 r/	8,910,000 r/	9,280,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 24, 2001.

3/ In adddition to the countries listed, Czech Republic, Madagascar, Namibia, and Slovakia produce feldspar, but output is not officially reported; available general information is inadequate for the formulation of reliable estimates of output levels.

4/ Reported figure.

5/ Data are for fiscal years beginning April 1 of that stated.

6/ In addition, the following quantities of aplite ore were produced in metric tons: 1996--365,580 (estimate); 1997--310,000 (estimate); 1998--310,000 (revised estimate); 1999--330,000 (revised); and 2000--330,000 (estimate).

7/ Excludes nepheline syenite.

8/ Includes pegmatite.

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FERROALLOYS

By Michael D. Fenton

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production table was prepared by Glann J. Wallace, international data coordinator.

Ferroalloys are alloys of iron that contain one or more other chemical elements. These alloys are used to add these other elements into molten metal, usually in steelmaking. The top five ferroalloy producers in the world in 2000, in decreasing order, were China, South Africa, Norway, Russia, and Ukraine. Ferroalloys impart distinctive qualities to steel or cast iron or serve important functions during the production cycle. The ferroalloy industry is closely associated with the iron and steel industry, its largest customer. World production in 2000 of the bulk ferroalloys chromium, manganese, and silicon, was estimated at 16.6 million metric tons (Mt). U.S. bulk ferroalloy reported consumption in 2000 was 1.1 Mt.

The principal ferroalloys are those of chromium, manganese, and silicon. Manganese is essential to the production of virtually all steels and is important to the production of cast iron. Manganese is used to neutralize the harmful effect of sulfur and as an alloying element. Silicon is used primarily for deoxidation in steel and as an alloying element in cast iron. Boron, chromium, cobalt, columbium, copper, molybdenum, nickel, phosphorus, titanium, tungsten, vanadium, zirconium, and the rare-earth elements are among the other elements contributing to the character of the various alloy steels and cast irons (Brown and Murphy, 1985, p. 265).

Compared with the major ferroalloy-producing countries, U.S. ferroalloy production is moderate in silicon and manganese, but relatively low in other ferroalloy metals. Consequently, U.S. ferroalloy production meets only a small percentage of domestic demand. One important exception is ferrosilicon. For all forms of silicon, the United States has been meeting about 70% of its needs. In countries with competitive mineral resources, the trend is toward production of value added products, particularly in the case of chromium. Because of the unlikely prospect of new or expanded U.S. production and because of the uncompetitive U.S. mineral resources for most of the ferroally metals, the overall domestic ferroalloy production trend is one of decline. Nickel and chromium are prime examples. By 1999, U.S. production of ferronickel and common grades of ferrochromium had ceased. In both cases, when production stopped, resources were low-grade, producers were relying on imported ore for feedstock, and operating costs were high. In contrast, ferrosilicon and manganese ferroalloy production have fluctuated, but have been relatively strong (Sibley and others, 2001, p. 33).

In the major ferroalloys and probably some specialty ferroalloys, alternative materials to ferroalloys use, principally alloy scrap and oxide, overall have gained moderately on ferroalloys use per ton of steel production over the past 20 years. A combination of factors, including technology, availability, and price, is responsible for this general decline in unit consumption of the ferroalloy form, and ferroalloy metal from all sources, for the major ferroalloys in steelmaking. U.S. customer needs for ferroalloys in alloy and stainless steel for a multitude of applications have been and will continue to be strong, even while the steel industry continues to improve processing technology to reduce raw materials needs, and metallurgists develop steel grades with lower alloying metal content and equal or better performance to lower costs. For many stainless steel applications there are no acceptable substitutes, and its key constituents, chromium and nickel, are essential. As technology and industry practices result in greater efficiency of use of ferroalloys, the strong demand for metals in construction, the chemical industry, transportation, and household appliances is expected to more than offset any basic reduction in unit consumption in the future. Competition from other materials, such as plastics and nonferrous metals in the transportation sector, will be strong, but the use of lightweight, high-strength grades is expected to make steel competitive for many years (Sibley and others, 2001, p. 40).

Chromium, manganese, silicon, and other ferroalloys are discussed in more detail, including domestic data coverage and outlook, and U.S. Government stockpile, in the respective commodity chapters in the U.S. Geological Survey Minerals Yearbook. These chapters are also published individually in the Mineral Industry Surveys Annual Review series. The tables in this chapter contain information on all ferroalloys for which data are available.

The major world chromite ore producing countries in 2000 were India, Kazakhstan, South Africa, and Turkey. Brazil, Finland, and Zimbabwe were significant chromite ore producing countries. Most chromite ore was smelted in electric-arc furnaces to produce ferrochromium for use by the metallurgical industry. Stainless steel manufacture consumed most ferrochromium. The country with the largest ferrochromium production was South Africa. China, Finland, India, Kazakhstan, Russia, and Zimbabwe were also significant ferrochromium producing countries. The major stainless steel producing areas of the world—Europe (including Western Europe and Scandinavia), Asia (Japan, Korea, and Taiwan), and the United States—account for about 80% of world stainless steel production.

The ferrochromium industry developed in close proximity to the stainless steel industry. However, the closing of ferrochromium facilities in these historically-producing areas has resulted in the migration of ferrochromium production capacity to chromite-producing areas. The world chromium industry in 2000 operated with production capacity in excess of demand. In South Africa, ferrochromium production capacity was brought on-stream and new furnaces were planned and under construction. Four industry trends were evolving—ferrochromium production using an environmentally friendly, and energy- and recovery-efficient, prereduction, closed-furnace process; chromium recovery from ferrochromium slag; consolidation of ownership in both the ferrochromium and stainless steel production industries; and strategic alliances between the latter two industries.

Manganese ferroalloys, consisting of various grades of

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ferromanganese and silicomanganese, are used to provide a key ingredient for steelmaking (Matricardi and Downing, 1995, p. 970). Most U.S. supply was imported. The leading foreign source of ferromanganese and silicomanganese was South Africa, whose exports of manganese ferroalloys to the United States were greater than those of the next three largest sources combined (Australia, Kazakhstan, and Mexico). Manganese ferroalloys were produced domestically only at a plant near Marietta, OH, which was owned by France's Eramet. Eramet and Billiton plc of the United Kingdom accounted for a significant portion of the world's production of manganese ferroalloys. Eramet controlled plants in China, France, Italy, and Norway, and Billiton controlled plants in Australia and South Africa. On a country basis, China was by far the largest producer of manganese ferroalloys, with an output greater than that of South Africa and Ukraine combined, the countries with the next largest production.

Demand for silicon ferroalloys is driven principally by the production of steel and cast iron (Dosaj, 1997, p. 1115). On the basis of content, U.S. production of silicon ferroalloys declined to less than 50% of apparent consumption of ferrosilicon because of a significant increase in imports. Norway was the leading source of U.S. imports. China was estimated to be the world's largest producer of ferrosilicon, with production more than twice that of either Norway or Russia, the countries with the next largest production. This chapter includes data for silicon metal, which generally was produced like ferrosilicon in submerged-arc electric furnaces. Silicon metal was not used as a ferroalloy, but rather for alloying with aluminum and for production of chemicals, especially silicones (Dosaj, 1997, p. 1108).

References Cited

Brown, R.E., and Murphy, G. F., 1985, Ferroalloys, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 265-275.

Dosaj, Vishu, 1997, Silicon and silicon alloys—Chemical and metallurgical, *in* Kirk-Othmer encyclopedia of chemical technology (4th ed.): New York, John Wiley and Sons, v. 21, p. 1104-1122.

Matricardi, L.R., and Downing, James, 1995, Manganese and manganese alloys, *in* Kirk-Othmer encyclopedia of chemical technology (4th ed.): New York, John Wiley and Sons, v. 15, p. 963-990.

Sibley, S.F., Blossom, J.W., Cunningham, L.D., Fenton, M.D., Gambogi, Joseph, Jones, T.S., Kuck, P.H., Papp, J.F., Reese, R.G., Jr., and Shedd, K.B., 2001, Trends in U.S. customer needs for ferroalloys, *in* The Ninth International Ferroalloys Congress and the Manganese 2001 Health Issues Symposium, Quebec City, Canada, June 3-6, 2001, Proceedings: Washington, DC, The Ferroalloys Association, p. 29-58.

TABLE 1
GOVERNMENT INVENTORY OF FERROALLOYS, DECEMBER 31, 2000 1/

Alloy		Stockpile grade	Nonstockpile grade	Total
Ferrochromium:	metric tons of alloy			
High-carbon	do.	560,000	601	561,000
Low-carbon	do.	263,000	6,890	270,000
Ferrochromium-silicon	do.	11,900	230	12,100
Ferrocolumbium	metric tons of contained columbium	52	--	52
Ferromanganese, high carbon	metric tons of alloy	772,000	--	772,000
Ferrotungsten	kilograms of contained tungsten	240,000	357,000	598,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Defense National Stockpile Center; Inventory of Stockpile Material R-1.

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TABLE 2
REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ADDITIVES BY END USE IN 2000 1/ 2/

(Metric tons of alloys unless otherwise specified)

End use	FeB	Manganese		FeP	FeSi	FeTi
		FeMn	SiMn			
Steel:						
Carbon	827	254,000 3/	79,500	4,180	36,700 3/ 4/	4,180
Stainless and heat-resisting	115	15,200 3/	6,350	(5/)	52,700	1,520
Other alloy	97	22,100 3/	19,600	656	12,600 3/	185
Tool	--	(3/)	(3/)	--	24,100 3/	(5/)
Unspecified	--	826	275	(5/)	10,500	--
Total	1,040	292,000	106,000	4,830	137,000	5,890
Cast irons	--	9,170	1,340	1,790	114,000	60
Superalloys	(6/)	(6/)	--	(7/)	118 8/	918
Alloys (excluding alloy steels and superalloys)	393	20,500	(4/)	(7/)	(4/ 8/)	734
Miscellaneous and unspecified	--	(6/)	(4/)	(7/)	241,000	7
Grand total	1,430	321,000	107,000	6,620	492,000	7,610
Total 1999	1,710	316,000	118,000	6,400 r/	481,000	7,410 r/
Percentage of 1999	84	102	91	103	102	103
Consumer stocks, December 31	312	36,200 9/	10,700 9/	1,150	16,300	788

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ FeB, ferroboron, includes other boron materials; FeMn, ferromanganese, includes manganese metal; SiMn, silicomanganese; FeP, ferrophosphorus, includes other phosphorus materials; FeSi, ferrosilicon, includes silicon metal, silvery pig iron, inoculant alloys; FeT, ferrotitanium, includes titanium scrap, other titanium materials.

3/ All or part included with "Steel: Unspecified."

4/ All or part withheld to avoid disclosing company proprietary data.

5/ Included with "Steel: Other alloy."

6/ Included with "Alloys (excluding alloy steels and superalloys)."

7/ All or part included with "Cast irons."

8/ Part included with "Miscellaneous and unspecified."

9/ Includes producer stocks.

TABLE 3
REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ALLOYING ELEMENTS BY END USE IN 2000 1/ 2/

(Metric tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeNb	FeNi	FeV	FeW
Steel:						
Carbon	6,990	347	1,370	--	2,110	--
Stainless and heat-resisting	162,000	485	682	13,200	W	(3/)
Other alloy	28,000	2,360	1,090	85	790	(3/)
Tool	1,860	398	(4/)	--	43	(3/)
Unspecified	--	--	--	--	--	(3/)
Total	199,000	3,590	3,140	13,300	2,940	388
Cast itons	5,140	523	--	(5/)	W	--
Superalloys	7,080	W	1,060	--	15	(3/)
Alloys (Excluding alloy steels and superalloys)	1,740	102	W	135	2	(3/)
Miscellaneous and unspecified	W	51	10	(5/)	75	--
Grand total	213,000	4,270	4,210	13,500	3,030	388
Total 1999	212,000 r/	4,350 r/	3,460 r/	12,800 r/	3,160 r/	484
Percentage of 1999	101	98	122	105	96	80
Consumer stocks, December 31	15,100	197	NA	768	299	33

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ FeCb, ferrocolumbium, including nickel columbium; FeCr, ferrochromium, including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum, including calcium molybdate; FeNi, ferronickel; FeW, ferrotungsten; and FeV, ferrovanadium, including other vanadium-carbon-iron ferroalloys.

3/ Included with "Total steel."

4/ Included with "Steel: Other alloy."

5/ All or part included with "Alloys (excluding alloy steels and superalloys)."

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TABLE 4
FERROALLOY PRICES IN 2000

	High	Low	Average 1/
Chromium:			
Charge-grade ferrochromium 2/	43.00	37.00	41.44
High-carbon ferrochromium 2/	43.00	37.00	40.13
Low-carbon ferrochromium 2/	76.00	60.00	69.33
Columbium:			
High-purity (vacuum-grade) ferrocolumbium 3/	18.00	17.50	17.75
Regular-grade ferrocolumbium 3/	7.00	6.75	6.88
Manganese:			
Medium-carbon ferromanganese 2/	54.00	35.00	46.00
Standard-grade ferromanganese 4/	530.00	450.00	488.00
Silicomanganese 5/	27.50	19.50	23.80
Molybdenum:			
Ferromolybdenum 3/	3.70	2.90	3.50
Molybdenum oxide 3/	2.98	2.15	2.59
Silicon:			
50% ferrosilicon 2/	47.00	43.00	45.00
75% ferrosilicon 2/	39.00	33.00	35.40
Silicon metal 5/	59.00	49.00	54.80
Vanadium, ferrovanadium 3/	6.80	3.50	5.05

1/ Annual time-weighted average.
2/ Cents per pound of contained element.
3/ Dollars per pound of contained element.
4/ Dollars per long ton.
5/ Cents per pound.

Sources: American Metal Market and Platt's Metals Week.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF FERROALLOYS AND FERROALLOY METALS IN 2000 1/

	Imports			Exports		
Alloy	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)
Ferroalloys:						
Chromium ferroalloys:						
Ferrochromium containing:						
More than 4% carbon	517,000	298,000	$212,000	33,500	22,200	$17,500
Not more than 4% carbon	XX	XX	XX	1,570	945	2,180
More than 3% but not more than 4% carbon	--	--	--	XX	XX	XX
More than 0.5% but not more than 3% carbon	9,150	5,930	6,470	XX	XX	XX
Not more than 0.5% carbon	50,300	32,700	50,400	XX	XX	XX
Ferrochromium-silicon	20,700	7,670	10,300	2,700	946	1,490
Total	597,000	344,000	279,000	37,700	24,100	21,200
Manganese ferroalloys:						
Ferromanganese containing:						
More than 4% carbon	212,000	164,000	83,200	XX	XX	XX
More than 1% but not more than 2% carbon	77,700	62,900	48,900	XX	XX	XX
Not more than 1% carbon	22,300	18,800	19,200	XX	XX	XX
Ferromanganese, all grades	XX	XX	XX	7,950	XX	5,290
Silicomanganese	378,000	252,000	169,000	1,870	XX	1,200
Total	690,000	498,000	320,000	9,820	XX	6,490
Silicon ferroalloys:						
Ferrosilicon containing:						
More than 55% silicon	420	344	204	11,800	7,420	9,290
More than 55% but not more than 80% silicon and more than 3% calcium	6,430	4,780	3,840	XX	XX	XX
More than 55% but not more than 80% silicon and not more than 3% calcium	275,000	208,000	158,000	XX	XX	XX
Magnesium ferrosilicon	26,600	12,100	21,700	XX	XX	XX
Ferrosilicon, other 2/	13,400	5,630	10,100	31,500	15,000	32,600
Total	322,000	231,000	193,000	43,300	22,400	41,900

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF FERROALLOYS AND FERROALLOY METALS IN 2000 1/

Alloy	Imports			Exports		
	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)
Ferroalloys--Continued:						
Other ferroalloys:						
Ferrocerium and other pyrophoric alloys	133	NA	$1,560	XX	XX	XX
Ferromolybdenum	8,310	5,310	35,600	23,600	NA	$104,000
Ferronickel	40,800	16,400	125,000	61	37	202
Ferroniobium (columbium)	6,770	NA	62,100	60	NA	526
Ferrophosphorus	13,000	NA	3,310	4,510	NA	3,110
Ferrotitanium and ferrosilicon-titanium	6,050	NA	15,900	1,090	NA	2,990
Ferrotungsten and ferrosilicon-tungsten	610	470	2,600	6	4	62
Ferrovanadium	3,340	2,510	24,900	229	172	2,360
Ferrozirconium	281	NA	548	213	NA	482
Ferroalloys, other	31,400	NA	42,400	3,020	NA	6,380
Total	111,000	XX	314,000	32,800	XX	120,000
Total ferroalloys	1,720,000	XX	1,110,000	124,000	XX	190,000
Metals:						
Chromium	9,940	XX	59,400	1,260	XX	13,100
Manganese, other:						
Unwrought	15,100	NA	22,100	2,220	NA	5,020
Other	664	NA	2,270	XX	XX	XX
Silicon:						
Less than 99% silicon	37,200	35,900	39,000	11,500	11,100	17,400
Less than 99.99% but not less 99% silicon	94,100	92,500	111,000	1,460	1,450	1,850
Not less than 99.99% silicon	1,580	XX	269,000	189,000	XX	334,000
Total	159,000	XX	503,000	205,000	XX	371,000
Grand total	1,880,000	XX	1,610,000	329,000	XX	561,000

NA Not available. XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes less than 55% silicon and greater than 80% silicon.

Source: U.S. Census Bureau.

TABLE 6
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Albania, electric furnace, ferrochromium	31,189	31,144 r/	30,252 r/	28,120 r/	9,900
Argentina, electric furnace:					
Ferromanganese	7,374	8,381	5,016	2,000 r/ e/	--
Ferrosilicon	22,452	17,835	11,245	2,568 r/	7,000
Silicomanganese	24,654	26,134	25,388	10,000 r/ e/	--
Silicon metal	--	--	7,000	8,000 e/	8,000
Other 6/	21,286	14,223	22,974	20,000 e/	20,000
Total	75,766	66,573	71,623 r/	42,600 r/ e/	35,000
Australia, electric furnace: e/					
Ferromanganese	110,000	95,000	110,000	98,000 r/	115,000
Silicomanganese	95,000	95,000	105,000	116,000 r/	135,000
Silicon metal	30,000	30,000	30,000	30,000	30,000
Total	235,000	220,000	245,000	244,000 r/	280,000
Austria, electric furnace: e/					
Ferronickel	5,000 7/	5,000	4,500	4,250	4,200
Other	5,900	5,900	5,000	5,000	5,000
Total	10,900 7/	10,900	9,500	9,250	9,200
Belgium, electric furnace, ferromanganese e/ 8/	25,000	25,000	20,000	--	--
Bhutan, electric furnace, ferrosilicon e/	13,000	15,000	18,000	18,000	15,000
Bosnia and Herzegovina, electric furnace: e/					
Ferrosilicon	1,000	1,000	1,000	1,000	1,000
Silicon metal	200	200	200	200	200
Total	1,200	1,200	1,200	1,200	1,200

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Brazil, electric furnace:					
Ferrochromium 9/	77,231	74,485 r/	72,507 r/	90,784 r/	91,000
Ferrochromiumsilicon e/	5,000	5,000	5,000	5,000	5,000
Ferromanganese	215,260	153,000	122,000	85,300 r/	110,000
Ferronickel	29,582	32,015	26,389	19,807 r/	19,315 7/
Ferrosilicon	236,838	212,183	166,278	200,833 r/	200,000
Silicomanganese	232,218	175,000	124,000	148,400 r/	150,000
Silicon metal	150,054	136,884	126,744	136,572 r/	165,000
Other e/	76,000	76,000	76,000	76,000	76,000
Total	1,022,183	864,567 r/	718,918 r/	762,696 r/	816,000
Bulgaria, electric furnace: e/					
Ferrosilicon	8,300	8,000	8,000	8,000	8,000
Other	2,000	2,000	2,000	2,000	2,000
Total	10,300	10,000	10,000	10,000	10,000
Canada, electric furnace: e/					
Ferrosilicon	56,000	56,000	56,000	56,000	56,000
Ferrovanadium	1,000	1,000	1,000	1,000	1,000
Silicon metal	26,000	30,000	30,000	30,000	30,000
Total	83,000	87,000	87,000	87,000	87,000
Chile, electric furnace:					
Ferrochromium 9/	2,079	-- r/	-- r/	-- r/	--
Ferromanganese	8,498	5,517	3,652	3,700 e/	3,700
Ferromolybdenum	4,222	3,157	1,978	2,000 e/	2,000
Ferrosilicon	4,650	1,294	1,159	1,160 e/	1,160
Silicomanganese	1,599	3,175	3,921	3,950 e/	3,950
Total	21,048	13,143 r/	10,710 r/	10,800 r/ e/	10,800
China: e/					
Blast furnace:					
Ferromanganese	450,000	500,000	550,000	550,000 r/	500,000
Other	200,000	100,000	48,000	100,000	100,000
Electric furnace:					
Ferrochromium	423,000	480,000	424,000	400,000	450,000
Ferromanganese	700,000	680,000	500,000	550,000	520,000
Ferrosilicon	1,490,000	1,250,000	1,290,000	1,120,000 r/	1,400,000
Silicomanganese	840,000	770,000	639,000	822,000 r/	900,000
Other	77,000	260,000	110,000	258,000 r/	160,000
Total	4,180,000	4,040,000	3,560,000	3,800,000	4,030,000
Colombia, electric furnace, ferronickel	52,241	55,079	61,180	61,620	63,000
Croatia, electric furnace, ferrochromium	10,559	24,231	11,770	-- r/	15,753 7/
Czech Republic, electric furnace, other e/	1,000	1,000	1,000	1,000	1,000
Dominican Republic, electric furnace, ferronickel	78,488	84,897	69,419 r/	61,561 r/	70,000
Egypt, electric furnace: e/					
Ferromanganese	35,000	26,000 r/	18,000 r/	30,000 r/	30,000
Ferrosilicon	44,000	44,000	44,000	44,000	45,000
Total	79,000	70,000 r/	62,000 r/	74,000 r/	75,000
Finland, electric furnace, ferrochromium	227,811	236,652	230,906	256,290 r/	260,600 7/
France: e/					
Blast furnace, ferromanganese	337,000 7/	326,000 7/	321,000	302,000 7/	300,000
Electric furnace:					
Ferromanganese	100,000 7/	100,000 7/	100,000	138,000 r/	140,000
Ferrosilicon	103,000	109,000	110,000	110,000	110,000
Silicomanganese 10/	61,000	66,000	65,000	55,000 r/	60,000
Silicon metal	73,800 7/	74,000	75,000	75,000	75,000
Other	20,000	20,000	20,000	20,000	20,000
Total	695,000	695,000	691,000	700,000 r/	705,000
Georgia, electric furnace: e/					
Ferromanganese	7,600	4,000	10,000	6,500 r/	7,000
Silicomanganese	7,000	16,600	35,000	25,000 r/	25,000
Total	14,600	20,600	45,000	31,500 r/	32,000

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Germany, electric furnace: e/					
Ferrochromium	25,303 7/	25,856 7/	20,879 7/	16,960 7/	17,000
Ferromanganese	10,000 r/	-- r/	-- r/	-- r/	--
Silicon metal	20,000	20,000	20,000	20,000	26,000
Other 11/	30,000	30,000	30,000	30,000	30,000
Total	85,300 r/	75,900 r/	70,900 r/	67,000 r/	73,000
Greece, electric furnace, ferronickel	71,204	70,440	60,020	59,545 r/	81,662 7/
Hungary, electric furnace: e/ 12/					
Ferrosilicon	7,000	7,000	7,000	7,000	7,000
Silicon metal	1,000	1,000	1,000	1,000	1,000
Total	8,000	8,000	8,000	8,000	8,000
Iceland, electric furnace, ferrosilicon	70,520	70,000 e/	68,000	70,900 r/	70,000
India, electric furnace: e/					
Ferrochromium 13/	261,666 7/	286,973 7/	345,125 7/	350,000	352,000
Ferrochromiumsilicon	9,000	10,000	10,000	10,000	10,000
Ferromanganese	190,000	166,000	165,000	160,000	160,000
Ferrosilicon	78,000	74,000	55,000 r/	55,000	60,000
Silicomanganese	170,000	198,000	193,000	190,000	185,000
Other	8,500	9,000	9,000	9,000	9,000
Total	717,000	744,000	777,000 r/	774,000	776,000
Indonesia, electric furnace:					
Ferromanganese e/	14,000	15,000	13,000	12,000 r/	12,000
Ferronickel	47,800	50,000	42,260	46,030 r/	50,550 7/
Silicomanganese e/	7,000	7,000	7,000	7,000	7,000
Total	68,800	72,000 e/	62,260	65,030 r/	69,600
Iran, electric furnace:					
Ferrochromium	10,500	11,450	13,745	13,680 r/	14,000
Ferrosilicon e/	40,000 r/	40,000 r/	40,000 r/	46,000 r/	40,000
Total e/	50,500 r/ 7/	51,500 r/	53,700 r/	60,000 r/	54,000
Italy, electric furnace:					
Ferrochromium	29,915	11,295	11,487	12,000 e/	12,000
Ferromanganese	25,143	40,000 r/	49,000 r/	19,000 r/	40,000
Silicomanganese e/	100,353 7/	100,000	70,000 r/	67,000 r/	90,000
Silicon metal	14,433 r/	12,619 r/	8,094 r/	6,257 r/	5,000
Other e/ 14/	10,000	10,000	10,000	10,000	10,000
Total e/	180,000 r/	174,000 r/	149,000 r/	114,000 r/	157,000
Japan, electric furnace:					
Ferrochromium 8/	193,695	186,432	142,931	119,777	130,074 7/
Ferromanganese	343,104	376,633	334,081	315,152	337,694 7/
Ferronickel	328,699	352,841 r/	345,772	332,293 r/	367,181 7/
Ferrosilicon	--	--	951	1,452	-- 7/
Silicomanganese	75,802	78,323	70,886	65,744	67,926 7/
Other 15/	10,131	10,217	8,678	12,860 r/	15,020 7/
Total	951,431	1,004,446 r/	903,299	847,278 r/	917,895 7/
Kazakhstan, electric furnace:					
Ferrochromium	352,000	600,000	535,000	597,946	640,000
Ferrochromiumsilicon e/	20,000	48,000	33,550 7/	60,000	65,000
Ferromanganese	--	--	--	--	5,000
Ferrosilicon e/	119,000	133,000	92,000	120,000	120,000
Silicomanganese	50,000	55,000	57,000	75,000	100,000
Other	10,000	9,000	8,000	9,000 e/	9,000
Total	551,000	845,000	725,550	861,946 r/	939,000
Korea, North, electric furnace: e/					
Ferromanganese 11/	6,000	6,000	6,000	6,000	6,000
Ferrosilicon	3,000	3,000	3,000	3,000	3,000
Other 12/	1,000	1,000	1,000	1,000	1,000
Total	10,000	10,000	10,000	10,000	10,000
Korea, Republic of, electric furnace:					
Ferromanganese	126,135	158,755	158,418	140,208 r/	140,000
Silicomanganese	83,375	77,375 r/	106,997	116,091 r/	110,000
Other	4,687	2,174	2,785 r/	4,639 r/	4,000
Total	214,197	238,304 r/	268,200 r/	260,938 r/	254,000

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Macedonia, electric furnace:					
Ferrochromium	3,780	460	--	--	--
Ferronickel	7,900	14,000	15,200	5,000	--
Ferrosilicon e/	57,220 7/	55,000	55,000	50,000	50,000
Silicon metal e/	1,000	1,000	500	--	--
Total e/	69,900	70,500	70,700	55,000	50,000
Mexico, electric furnace: 16/					
Ferromanganese	69,000	68,000	87,000	79,000	91,000
Silicomanganese	93,000	105,000	105,000	114,000	108,000
Total	162,000	173,000	192,000	193,000	199,000
New Caledonia, electric furnace, ferronickel	168,700	159,018 r/	157,959	157,592	157,000
Norway, electric furnace: e/					
Ferrochromium	108,900 7/	145,124 7/	174,678 7/	159,714 7/	165,000
Ferromanganese	215,000 7/	235,000	235,000	235,000	235,000
Ferrosilicon	462,423 7/	470,000	470,000	460,000 r/	460,000
Silicomanganese	210,000	230,000	230,000	230,000	230,000
Silicon metal	110,000	110,000	110,000	100,000	100,000
Other 10/	15,000	15,000	15,000	15,000	15,000
Total	1,120,000	1,210,000	1,230,000	1,200,000 r/	1,210,000
Peru, electric furnace, ferrosilicon e/	600	600	600	600	600
Philippines, electric furnace, ferrochromium	6,736	--	--	--	--
Poland:					
Blast furnace, ferromanganese	59,900	47,500 e/	50,152	60,000 e/	60,000
Electric furnace:					
Ferrochromium	1,100 r/	6,200 r/	4,200 r/	3,500 e/	3,500
Ferrosilicon	71,800	77,300	75,000	62,481 r/	70,000
Silicomanganese	25,000	20,000	15,100 r/	25,000	25,000
Silicon metal e/	1,300	1,400	1,400	1,200	1,500
Other e/	4,500 r/	7,300 r/	11,848 r/ 7/	20,000	20,000
Total	163,600 r/	159,700 r/	157,700 r/	172,181 r/	180,000
Romania, electric furnace:					
Ferrochromium	9,650	950	873	--	--
Ferromanganese	20,150	11,505	4,170 e/	25 e/	1,044 7/
Ferrosilicon	23,827	9,620	5,553	5,000 e/	5,000
Silicomanganese	78,590	62,570	83,617	550 e/	21,158 7/
Silicon metal e/	300	300	150	--	--
Total e/	133,000	84,900	94,400	5,580	27,200
Russia: e/					
Blast furnace:					
Ferromanganese	67,000 7/	47,100 7/	65,000 7/	90,000	70,700
Ferrophosphorus	2,300 7/	3,600 7/	3,500	3,500	3,500
Spiegeleisen	7,000	7,000	7,000	7,000	7,000
Electric furnace:					
Ferrochromium	135,000	247,000	203,000 7/	249,000 7/	274,000 7/
Ferrochromiumsilicon	5,000	5,000	4,000	4,500	4,500
Ferronickel	75,000 7/	40,000	30,000	33,000	35,000
Ferrosilicon	460,000	510,000	496,000 7/	601,000 7/	652,000 7/
Silicon metal	40,000	40,000	40,000	40,000	40,000
Other	40,000	40,000	40,000	40,000	40,000
Total	831,000	940,000	889,000	1,070,000	1,130,000
Saudi Arabia, electric furnace, other e/	20,000	83,000	83,000	83,000	83,000
Serbia and Montenegro, electric furnace, ferronickel	6,501	6,338	1,243	--	--
Slovakia, electric furnace: e/					
Ferrochromium	19,900 7/	11,394 7/	11,715 7/	6,986 7/	7,000
Ferromanganese	25,000	20,000	20,000	20,000	20,000
Ferrosilicon	70,000 r/	50,133 r/ 7/	49,963 r/ 7/	70,000 r/	70,000
Silicomanganse	12,000	45,159 r/ 7/	46,627 r/ 7/	37,000 r/	35,000
Other	8,000	5,000	5,000	5,000	5,000
Total	135,000 r/	132,000 r/	133,000 r/	139,000 r/	137,000

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Slovenia, electric furnace:					
Ferrochromium	22,819	9,232	10,621	560	600
Ferrosilicon	10,000	8,000	8,000	8,000	8,000
Other e/ 6/	200	200	200	200	200
Total e/	33,000	17,400	18,800	8,760	8,800
South Africa, electric furnace:					
Ferrochromium 17/	1,478,000	1,939,500	2,025,300	2,155,202 r/	2,200,000
Ferromanganese	548,000 r/	499,000	542,000	527,000 r/	530,000
Ferrosilicon	87,000 r/	102,000	108,400 r/	106,000 r/	100,000
Silicomanganese e/	254,000 r/	286,000	265,000	267,000 r/ 7/	270,000
Silicon metal	28,500	34,000	32,600 r/	35,800 r/	34,000
Other e/ 18/	1,000	48,000	15,000	32,000 r/	30,000
Total e/	2,400,000 r/	2,910,000	2,990,000	3,120,000 r/	3,160,000
Spain, electric furnace:					
Ferrochromium	805	490	1,145	935	1,000
Ferromanganese e/	16,000 r/	23,000 r/	18,000 r/	10,000 r/	10,000
Ferrosilicon	35,890 r/	38,340 r/	39,115 r/	40,000 e/	40,000
Silicomanganese e/	102,000 r/	122,000 r/	108,000 r/	95,000 r/	100,000
Silicon metal	16,936 r/	19,220 r/	18,424 r/	28,000 r/ e/	30,000
Other e/	5,000	5,000	5,000	5,000	5,000
Total e/	177,000 r/	208,000 r/	190,000 r/	179,000 r/	186,000
Sweden, electric furnace:					
Ferrochromium	138,110	101,842	123,958	113,140	135,000
Ferrosilicon	21,287	22,409 r/	20,356 r/	21,440 r/	20,000
Total	159,397	124,251 r/	144,314 r/	134,580 r/	155,000
Taiwan, electric furnace:					
Ferromanganese	14,059	12,130	12,532	--	--
Ferrosilicon	2,481	3,391	3,775	3,212	3,000
Total	16,540	15,521	16,307	3,212	3,000
Turkey, electric furnace:					
Ferrochromium	101,450	108,320	110,175	110,000 e/	110,000
Ferrosilicon e/	4,460	4,730	4,810 7/	4,800	4,800
Total	105,910	113,050	114,985	115,000 e/	115,000
Ukraine: e/					
Blast furnace:					
Ferromanganese	100,000	125,000	112,400 7/	57,800	85,400
Spiegeleisen	2,500	2,500	2,500	2,500	5,400
Electric furnace:					
Ferromanganese	170,000	160,000	150,000	199,539 r/ 7/	252,679 7/
Ferronickel	8,300 7/	--	--	--	--
Ferrosilicon	250,000	300,000	222,511 7/	243,600 7/	323,417 7/
Silicomanganese	600,000	560,000	485,560 7/	498,905 7/	684,040 7/
Other	25,000	25,000	20,000	25,000	25,000
Total	1 160,000	1 170,000	993,000	1 030,000	1 380,000
United States, electric furnace:					
Ferrochromium 19/	36,800	60,700	W	W	W
Ferromanganese 20/	(21/)	W	W	W	W
Ferronickel	30,500	32,100	8,590	--	--
Ferrosilicon	362,000	359,000	334,000	325,000	250,000
Silicon metal	171,000	183,000	188,000	186,000	175,000
Other 22/	194,000	W	W	W	W
Total	795,000	635,000	531,000	511,000	425,000
Uruguay, electric furnace, ferrosilicon e/	200	200	200	200	200
Venezuela, electric furnace:					
Ferromanganese e/	--	--	8,000	11,000	--
Ferronickel	--	--	--	--	133 7/
Ferrosilicon e/	63,000	60,000	36,000 r/	57,000	60,000
Silicomanganese	53,034 r/	64,200 r/	48,504 r/	47,635 r/	50,000
Total e/	116,000 r/	124,000 r/	92,500 r/	116,000 r/	110,000
Zimbabwe, electric furnace:					
Ferrochromium	243,000	233,386	246,782	244,379 r/	246,324 7/
Ferrochromiumsilicon	33,175	17,000	21,000	16,267 r/	19,631 7/
Total	276,175	250,386	267,782	260,646 r/	265,955 7/

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, and alloy type 3/ 4/ 5/	1996	1997	1998	1999	2000 e/
Grand total:	17,900,000 r/	18,500,000 r/	17,400,000	17,900,000 r/	18,800,000
Of which:					
Blast furnace:					
Ferromanganese 23/	1,010,000	1,050,000	1,100,000	1,060,000 r/	1,020,000
Spiegeleisen 23/	9,500	9,500	9,500	9,500	12,400
Other 24/	202,000	104,000	51,500	104,000 r/	104,000
Total	1,230,000	1,160,000	1,160,000	1,170,000 r/	1,130,000
Electric furnace:					
Ferrochromium 25/	3,950,000	4,830,000 r/	4,750,000 r/	4,930,000 r/	5,130,000
Ferrochromiumsilicon	52,200	37,000	40,000	35,800 r/	39,100
Ferromanganese 26/ 27/	3,000,000 r/	2,890,000 r/	2,690,000	2,650,000	2,760,000
Ferronickel	910,000	902,000 r/	823,000 r/	781,000 r/	848,000
Ferrosilicon	4,280,000 r/	4,110,000 r/	3,900,000 r/	3,920,000 r/	4,260,000
Silicomanganese 27/ 28/	3,180,000 r/	3,160,000 r/	2,890,000 r/	3,020,000 r/	3,360,000
Silicon metal	685,000 r/	694,000 r/	689,000 r/	698,000 r/	721,000
Other 29/	590,000 r/	679,000 r/	501,000 r/	684,000 r/	585,000
Total	16,600,000	17,300,000 r/	16,300,000 r/	16,700,000 r/	17,700,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through August 21, 2001.

3/ In addition to the countries listed, Iran is believed to have produced ferromanganese and silicomanganese, but production figures are not reported; general informatio is inadequate for the formulation of reliable estimates of output levels. Production of ferrosilicon, manganese ferroalloys, and silicon metal began in 1996 in Saudi Arat but data for actual production were not available.

4/ To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operation is included with electric furnace production.

5/ To the extent possible, ferroalloy production of each country has been separated to show the following individual major types of ferroalloys: ferrochromium, ferrochromiumsilicon, ferromanganese, ferronickel, ferrosilicon, silicomanganese, silicon metal, and spiegeleisen. Ferroalloys other than those listed that have been identifie specifically in sources, as well as those ferroalloys not identified specifically but which definitely exclude those listed previously in this footnote, have been reported as "Other." Where one or more of the individual ferroalloys listed separately in this footnote have been inseparable from other ferroalloys owing to a nation's reporting system, deviations are indicated by individual footnotes.

6/ Includes calcium-silicon.

7/ Reported figure.

8/ Includes silicomanganese, if any.

9/ Includes high- and low-carbon ferrochromium.

10/ Includes silicospiegeleisen, if any.

11/ Includes ferrochromiumsilicon and ferronickel, if any.

12/ Hungary is believed to produce some blast furnace ferromanganese.

13/ Includes charge chrome and ferrochrome.

14/ Excludes calcium-silicon.

15/ Includes calcium-silicon, ferrocolumbium, ferromolybdenum, ferrotungsten, ferrovanadium, and other ferroalloys.

16/ Salable products from Autlán.

17/ Includes production from Bophuthatswana and net production of ferrochromiumsilicon, if any.

18/ Includes ferronickel, if any.

19/ U.S. output includes chromium metal, high- and low-carbon ferrochromium, ferrochromiumsilicon, and other chromium materials.

20/ U.S. output of ferromanganese includes manganese metal and silicomanganese.

21/ Withheld to avoid disclosing company proprietary data; included with "Other."

22/ May include ferroboron, ferrocolumbium, ferromolybdenum, ferrophosphorus, ferrotitanium, ferrotungsten, ferrovanadium, nickel columbium, and silvery pig iron.

23/ Spiegeleisen, if any, for Germany is included with blast furnace ferromanganese.

24/ Includes ferrophosphorus and data contained in "Blast furnace: Other."

25/ Ferrochromium includes ferrochromiumsilicon, if any, for Japan, South Africa, and the United States.

26/ Ferromanganese includes silicomanganese, if any, for North Korea.

27/ U.S. production is included with "Other."

28/ Includes silicospiegeleisen, if any, for France.

29/ Includes calcium-silicon, ferromolybdenum, ferrovanadium, silicomanganese for the United States, and data contained with "Electric furnace: "Other" for each country indicated.

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FLUORSPAR

By M. Michael Miller

Domestic survey data and tables were prepared by Cindy Chen, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Traditionally, fluorspar has been considered to be vital to the Nation's national security and economy. It is used directly or indirectly to manufacture such products as aluminum, gasoline, insulating foams, refrigerants, steel, and uranium fuel. Most fluorspar consumption and trade involve either acid grade, which is greater than 97% calcium fluoride (CaF_2), or subacid grade, which is 97% or less CaF_2. The latter includes metallurgical and ceramic grades and is commonly called metallurgical grade.

All domestic sources of fluorspar are derived from sales of material from the national defense stockpile (NDS) and from a small amount of synthetic fluorspar produced from industrial waste streams. Byproduct fluorosilicic acid production from some phosphoric acid producers supplements fluorspar as a domestic source of fluorine, but is not included in fluorspar production or consumption calculations. According to the U.S. Census Bureau and the U.S. Geological Survey (USGS), imports of fluorspar increased by 9% compared with those of 1999. Hydrofluoric acid (HF) imports also increased by 9% when compared with those of 1999.

Legislation and Government Programs

In accordance with the Strategic and Critical Materials Stock Piling Act as amended (50 U.S.C. 98h-2), the Defense National Stockpile Center (DLA-DNSC) of the Defense Logistics Agency was authorized to sell about 54,400 metric tons (t) (60,000 short dry tons) of metallurgical-grade fluorspar during fiscal year 2000 (October 1, 1999, to September 30, 2000). During calendar year 2000, the DLA-DNSC sold about 54,400 t (60,000 short dry tons) of metallurgical grade. According to the DLA-DNSC's fiscal year 2001 (October 1, 2000, to September 30, 2001) annual materials plan, total sales of about 54,400 t (60,000 short dry tons) of metallurgical grade were authorized. See the section on stocks for unsold quantities remaining in the NDS.

Production

In 2000, there was no reported domestic mine production of fluorspar, and there is no data survey for byproduct fluorspar. Domestic production data for fluorosilicic acid were developed by the USGS from voluntary surveys of U.S. operations. Of the 11 fluorosilicic acid operations surveyed, 10 respondents reported production, and 1 respondent reported zero production, representing 100% of the quantity reported.

Hastie Mining Co. washed, screened, and dried metallurgical- and acid-grade fluorspar imported or purchased from the NDS. Seaforth Mineral & Ore Co., Inc., dried and screened imported or NDS fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, as did Applied Industrial Materials Corp. at its facility at Aurora, IN.

In 2000, 6 companies operated 10 plants that processed phosphate rock for the production of phosphoric acid, that generated 68,000 t of byproduct fluorosilicic acid. They sold or used 67,800 t of byproduct fluorosilicic acid at a value of about $10 million. This was equivalent to approximately 119,000 t of fluorspar (grading 92% CaF_2) sold or used. This was essentially unchanged from the level of fluorosilicic acid output reported in 1999. Because fluorosilicic acid is a byproduct of the

Fluorspar in the 20th Century

In 1900, U.S. fluorspar production was 16,700 metric tons, with more than 80% of it mined in Caldwell, Crittenden, and Livingston Counties in Kentucky. The remainder of the output came from the well-known mining district near Rosiclare in Hardin County, IL. Processing of the product simply consisted of washing and screening, although in 1900, two producers were building facilities to grind the fluorspar prior to sale. In 1920, the flotation process was introduced, which allowed production of fluorspar of more than 97% purity, which became known as acid-grade fluorspar. At the beginning of the 20th century small amounts of fluorspar were consumed for ceramics, enamels, foundry work, glass, hydrofluoric acid, and steel. Since the introduction of the open hearth furnace to the United States in 1888, however, the use of fluorspar as a flux in steelmaking had been increasing.

For most of the century, demand for fluorspar grew steadily, driven during the first quarter of the century almost entirely by the steel market and, from the 1930s on, by the steel market and the development of chlorofluorocarbons (CFCs), which provided a new market for hydrofluoric acid (HF). Demand peaked in 1974, when U.S. consumption reached 1.38 million metric tons, at which time about 55% of consumption was acid-grade fluorspar and 45% was metallurgical-grade fluorspar. During the last quarter of the century, fluorspar's use in steelmaking decreased dramatically, and CFC production was discontinued for environmental reasons. By the end of the century, domestic annual consumption of fluorspar had leveled off in the 500,000- to 600,000-ton range, with consumption for HF production accounting for about 80% of apparent consumption. During the 20th century, the U.S. fluorspar mining industry grew substantially and reached peak production during World War II, when shipments reached 375,000 tons in 1944. The postwar years would see the beginning of a trend of decreasing domestic production and increasing imports; by the end of the century domestic mining of fluorspar had ceased entirely.

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phosphate fertilizer industry and is not manufactured for itself alone, shortages may occur when phosphate fertilizer production goes down.

Some synthetic fluorspar was recovered as a byproduct of uranium processing, petroleum alkylation, and stainless steel pickling. The majority of the marketable product was estimated to come from uranium processing. At present, an estimated 5,000 to 8,000 t of synthetic fluorspar is produced annually in the United States.

Environment

The U.S. Environmental Protection Agency (EPA) released a review draft of its report titled "Estimates of U.S. Emissions of High-Global Warming Potential Gases and the Costs of Reductions." The preliminary draft report presented current forecasts of emissions of high-global-warming-potential gases (HGWPG) in the United States and assembled the available cost and market information on the technologies that could reduce these emissions. Using this information, marginal abatement curves were generated that attempted to quantify the achievable emission reductions at increasing values for carbon. The preliminary draft was released to solicit comments and additional information on the costs of reducing emissions of the HGWPG, which include hydrofluorocarbons (HFCs), perfluorocarbons, and sulfur hexafluoride (U.S. Environmental Protection Agency, March 2000, Estimates of U.S. emissions of high-global warming potential gases and the costs of reductions, accessed July 26, 2000, at URL http://www.epa.gov/ghginfo/new.htm).

Consumption

Domestic consumption data for fluorspar were developed by the USGS from voluntary surveys of U.S. operations (table 2). The consumption survey was sent to 40 operations quarterly and to 3 small operations annually. In 2000, on average, 35 operations responded to the consumption surveys, representing 88% of those operations surveyed. These respondents accounted for 98% of the reported U.S. consumption. Estimates for nonrespondents were based on past consumption levels, trends, and nonsurvey sources. Owing to the existence of additional consumers that are not surveyed, the reported consumption figures are estimated to constitute about 87% of the actual U.S. annual consumption.

Traditionally, there have been three grades of fluorspar: acid grade, containing more than 97% CaF_2; ceramic grade, containing 85% to 95% CaF_2; and metallurgical grade, containing 60% to 85% or more CaF_2. During the past several decades, there has been a general movement toward the use of higher quality fluorspar by many of the consuming industries. For example, welding rod manufacturers may use acid-grade fluorspar rather than ceramic grade, and some steel mills use ceramic or acid grade rather than metallurgical grade. The following is a discussion of the general uses of fluorspar by grade and, in the case of acid grade, the uses of some of its important downstream products.

Acid-grade fluorspar was used primarily as a feedstock in the manufacture of HF. Two companies reported fluorspar consumption for the production of HF, E.I. du Pont de Nemours and Co., Inc. (DuPont), and Honeywell International Inc.

The largest use of HF was for the production of a wide range of fluorocarbon chemicals, including HFCs, hydrochlorofluorocarbons (HCFCs), and fluoropolymers. HCFCs and HFCs were produced by the following eight companies: ATOFINA Chemicals, Inc. (formerly Elf Atochem North America, Inc.); Ausimont USA, Inc.; DuPont; Great Lakes Chemical Corp.; Honeywell; INEOS Fluor Americas LLC (formerly I.C.I. Americas, Inc.); La Roche Chemicals, Inc.; and MDA Manufacturing Ltd. MDA is a joint venture between Daikin America Inc. and 3M Corp. to produce HCFC 22 and hexafluoropropane for captive use in fluoropolymer manufacturing.

Some of the existing or potential fluorocarbon replacements for the banned chlorofluorocarbons (CFCs) are HCFCs 22, 123, 124, 141b, 142b, and 225. These HCFC substitutes have ozone-depletion potentials that are much lower than those of CFCs 11, 12, and 113, which together had accounted for more than 90% of CFC consumption. HCFC 22 has been used as a high-pressure refrigerant (e.g., in home air conditioning) for years; HCFC 123 is being used as a replacement for CFC 11 in low-pressure centrifugal chillers; HCFC 124 is a potential replacement for CFC 114 in medium-pressure centrifugal chillers and for CFC 12 as a diluent in sterilizing gas; and HCFCs 141b and 142b have replaced most of the CFCs 11 and 12 used in foam blowing. HCFCs 141b and 225, perfluorocarbons, and hydrofluoroethers have been introduced as replacements for CFC solvents. However, because of the current phaseout schedule for HCFCs, the market for HCFCs will exist for only a short time, and perfluorocarbons are on the list of gases that contribute to global warming. Of most immediate concern is the ban on production and importation of HCFC 141b, which is scheduled to go into effect January 1, 2003.

The HFC replacements have no ozone-depletion potential because they contain no chlorine atoms. The most successful HFC replacement compound is HFC 134a. It is the main replacement for CFC 12 in automobile air conditioners and is being used as the refrigerant in new commercial chillers and refrigerators and as the propellant in aerosols and tire inflators. HFCs 23, 32, 125, 143a, and 152a also are being produced domestically but in much smaller quantities. These HFCs hold potential for use individually or, more likely, in blends for specific uses, such as the azeotropic mixture of HFCs 32 and 125 that is emerging as the replacement of choice for HCFC 22. HFCs 134a and 227ea are being evaluated for use in medical aerosols. In 2000, Great Lakes Chemical and ICI Klea (now part of INEOS Fluor) announced that they were forming a joint venture to manufacture and supply HFC 227ea for use in measured dose inhalers. The new facility will be located at Great Lakes' facility in southern Arkansas (ICI Klea, February 9, 2000, INEOS Fluor in rally across Africa, accessed February 22, 2000, at URL http://www.klea.co.uk/news/view.cfm?id=51). HFC 227 also is an alternative to CFC 114, while HFC 245ca and HFC 356 are identified as possible long-term replacements for CFC 11 in chillers and for CFC 114 in high-temperature heat pumps. HFC 245fa may be a candidate for use as a low-pressure refrigerant to replace HCFC 123.

HFCs 134a, 245fa, 356, and 365mfc are being tested as potential replacements for HCFC 141b in blowing agents for thermosets, such as polyurethane. HFC 245fa appears to be further along in its development, and Honeywell has started construction of a new facility in Geismar, LA, to produce HFC 245fa for use in a range of foam-blowing applications in rigid polyurethane and polyisocyanurate foam insulation (Chemical Market Reporter, 2000). In a competing technology, ATOFINA

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announced the development of new technology to improve polyurethane foams manufactured with HFC 134a and other gaseous blowing agents. The new technology allows use of up to 75% HFC 134a while yielding foams similar to those blown with HCFC 141b. Further development and testing are required to confirm the commercial performance of the foams (ATOFINA Chemicals, Inc., January 24, 2001, ATOFINA Chemicals, Inc. announces development of improved technology for HFC-134a in insulation foam applications, accessed May 24, 2001, via URL http://www.atofinachemicals.com/whatsnew).

HFC 4310 has been developed as a replacement for CFC 113, HCFCs, and perfluorocarbons for use in drying fluids, cleaning and rinsing agents, defluxing agents, and heat-transfer media. DuPont has introduced a range of new specialty cleaning fluids for applications, including aerosol solvents, precision metal cleaning, defluxing and carrier fluids for applying lubricants. The new products are blends of HFC 4310 and HFC 365 that are stable, nonflammable, and have lower global warming potential than many previously existing products (Optical World, October 20, 2000, Cleaning fluid from DuPont, accessed June 15, 2001, at URL http://www.optical-world.co.uk/October%202000%20optiproducts.htm).

HCFCs 22, 123, and 124; HFCs 23, 125, 134a, and 227ea; and a number of other fluorine compounds have been approved by EPA as acceptable substitutes (some subject to use restrictions) for halon streaming agents for fire suppression.

CFC 113, HCFCs 22 and 142b, and HFC 152a were produced as chemical intermediates in the production of fluoropolymers. Fluoropolymers have desirable physical and chemical properties that allow them to be used in products from pipes and valves to architectural coatings to cookware. These intermediate uses of CFC 113 and HCFCs 22 and 142b will not be subject to the production phaseouts mandated by the Montreal Protocol and the Clean Air Act Amendments of 1990 because these products are consumed in the manufacturing process.

HF was consumed in the manufacture of uranium tetrafluoride, which was used in the process of concentrating uranium isotope 235 for use as nuclear fuel and in fission explosives. It also was used in stainless steel pickling, petroleum alkylation, glass etching, treatment of oil and gas wells, and as a cleaner and etcher in the electronics industry. HF was used as the feedstock in the manufacture of a group of inorganic fluorine chemicals that include chlorine trifluoride, lithium fluoride, sodium fluoride, sulfur hexafluoride, tungsten hexafluoride, and others that are used in dielectrics, metallurgy, wood preservatives, herbicides, mouthwashes, decay-preventing dentifrices, and water fluoridation.

Acid-grade fluorspar was used in the production of aluminum fluoride (AlF_3), which is the main fluorine compound used in aluminum smelting. In the Hall-Héroult aluminum process, alumina is dissolved in a bath of molten cryolite, AlF_3, and fluorspar to allow electrolytic recovery of aluminum. On average worldwide, the aluminum industry consumes about 23 kilograms of fluorides (measured as AlF_3 equivalent) for each metric ton of aluminum produced, ranging from 10 to 12 kilograms per metric ton (kg/t) in a modern prebaked aluminum smelter to 40 kg/t in an older Soderberg smelter without scrubbers. AlF_3 was added to the electrolyte in reduction cells to improve the cells' electrical efficiency. It was used by the ceramic industry for some body and glaze mixtures and in the production of specialty refractory products, and in the manufacture of aluminum silicates and in the glass industry as a filler. The AlF_3 manufactured for use in aluminum reduction cells is produced directly from acid-grade fluorspar or from byproduct fluorosilicic acid. About 82% of AlF_3 is produced from fluorspar and 18% from fluorosilicic acid (excluding China, the Commonwealth of Independent States, and Russia for which specific data are unavailable). In 2000, Alcoa World Chemicals, a business unit of Alcoa Inc., produced AlF_3 from fluorspar at Point Comfort, TX.

Ceramic-grade fluorspar was used by the ceramic industry as a flux and an opacifier in the production of flint glass, white or opal glass, and enamels. Ceramic grade was also used to make welding rod coatings and as a flux in the steel industry.

Metallurgical-grade fluorspar was used primarily as a fluxing agent by the steel industry. Fluorspar is added to the slag to make it more reactive by increasing its fluidity (by reducing its melting point) and thus increasing the chemical reactivity of the slag. Reducing the melting point of the slag brings lime and other fluxes into solution to allow the absorption of impurities. Fluorspar of different grades was used in the manufacture of aluminum, brick, cement, and glass fibers and by the foundry industry in the melt shop.

The U.S. steel industry reported high levels of production during the first half of 2000, but a slowing economy and increased imports resulted in a decrease in production of 11% in the second half. This was reflected in the industry's capacity utilization, which averaged 90% for the first half of the year but only 80% in the second half and by December had fallen to 72%. For the year, raw steel production was up by 4.2% (3.1% for basic oxygen process and 5.5% for electric arc process) compared with 1999.

The merchant-fluorspar market includes metallurgical-grade and acid-grade sales to steel mills, foundries, glass and ceramics plants, welding rod manufacturers, and other small markets in rail car, truckload, and less than truckload quantities. This merchant market is mature and in the United States amounts to about 115,000 metric tons per year (t/yr), equally divided between acid-grade and metallurgical-grade sales. Over the years, fluorspar usage in such industries as steel and glass has declined because of product substitutions or changes in industry practices.

The level of total reported fluorspar consumption was essentially unchanged in 2000 compared with that of 1999. Consumption of acid grade for HF and AlF_3 was essentially unchanged, but consumption for other uses decreased by 14%, although the data collected for non-HF/AlF_3 markets are believed to be underreported and may not accurately reflect the true size of these markets.

About 33,700 t of byproduct fluorosilicic acid valued at $4.98 million was sold for water fluoridation, about 20,400 t of fluorosilicic acid valued at $2.28 million was sold to make AlF_3 for the aluminum industry, and about 13,700 t valued at $2.78 million was sold or used for other uses, such as sodium silicofluoride production.

Stocks

Consumer stocks at yearend totaled 73,900 t, which was a decrease of 18% from 1999 levels. Consumer and distributor stocks totaled of 289,000 t, which included 215,000 t purchased from the NDS but still located at NDS depots. As of December 31, 2000, the NDS fluorspar inventory classified as excess (excluding material sold pending shipment) contained only about 112,000 t (123,000 short dry tons) of metallurgical-grade

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material. About 51% of the remaining metallurgical-grade material was classified as nonstockpile grade.

Transportation

The United States is import dependent for the majority of its fluorspar supply. Fluorspar is transported to customers by truck, rail, barge, and ship. Metallurgical grade is shipped routinely as lump or gravel, with the gravel passing a 75-millimeter (mm) sieve and not more than 10% by weight passing a 9.5-mm sieve. Acid grade is shipped routinely in the form of damp filtercake containing 7% to 10% moisture to facilitate handling and to reduce dust. Most acid-grade imports come from China and South Africa. Fluorspar is shipped by ocean freight using the "tramp" market for ships. Bulk carriers of 10,000 to 50,000 t deadweight normally are used. Participants negotiate freight levels, terms, and conditions.

Prices

According to Industrial Minerals magazine (London), yearend price ranges for Mexican fluorspar, free on board (f.o.b.) Tampico, were unchanged at $110 to $130 per metric ton for acid grade and $85 to $105 per ton for metallurgical grade, but increased to $132 to $145 per ton for low-arsenic acid grade (table 3). The range of South African prices for acid grade, f.o.b. Durban, remained unchanged at $105 to $125 per ton. No specific prices were available for Chinese fluorspar. According to Industrial Minerals magazine, the average U.S. Gulf port price, including cost, insurance and freight (c.i.f.), dry basis, for acid grade was $130 to $135 per ton. This would be the average delivered price of Chinese, Mexican, and South African acid grade at Gulf ports.

Prices of imported acid-grade fluorspar during the past 10 years have exhibited a roller-coaster pattern of highs and lows (figure 1). Prices have been affected by major factors, such as the severe drop in demand caused by the CFC phaseout, major increases in Chinese exports and the resulting cutthroat competition between Chinese exporters, and the introduction of Chinese export quotas and license fees. Lesser factors that affected prices were sales from the NDS and variations in shipping rates.

According to Chemical Market Reporter, the yearend 2000 price quotation for aqueous HF, 70%, in drums, f.o.b., freight allowed, was unchanged at $0.65 per pound. The quotation for chemically pure (99.0 weight percent) anhydrous HF, 1,300 pounds, f.o.b., was unchanged at $2.96 per pound. Quoted yearend prices for AlF_3 ranged from $825 to $1,408 per metric ton. Quoted prices for sodium fluoride, white, 97%, in 50- or 100-pound bags, drums, carloads, f.o.b. Tampa, was $0.60 per pound, and $0.63 per pound at El Paso. A price quote for fluorosilicic acid was unavailable.

Foreign Trade

According to the U.S. Census Bureau, U.S. exports of fluorspar decreased by 28% to 39,800 t from the 1999 figure (table 4). All U.S. exports were believed to be reexports of material imported into the United States or exports of material purchased from the NDS.

In 2000, imports for consumption of fluorspar increased by 9% when compared with those of 1999, according to the U.S. Census Bureau and USGS data (table 5). The largest suppliers of fluorspar to the United States were, in descending order, China, South Africa, and Mexico. China accounted for nearly 63% of U.S. fluorspar imports. The average c.i.f. unit value, in dollars per metric ton, was $128 for acid grade and $84 for metallurgical grade.

There are no tariffs on acid-grade or subacid-grade (metallurgical-grade) fluorspar from normal-trade-relations countries. There are no tariffs on other major fluoride minerals and chemicals, such as natural or synthetic cryolite, hydrofluoric acid, and aluminum fluoride.

Imports of HF increased by 9% to 131,000 t, or a quantity equivalent to about 196,000 t of fluorspar (table 6). Imports of synthetic and natural cryolite decreased by nearly 4% to 9,190 t, or a quantity equivalent to approximately 11,000 t of fluorspar (table 7). Imports of AlF_3 increased by 11% to 21,500 t, or a quantity equivalent to about 32,200 t of fluorspar (table 8).

World Review

World production increased by nearly 100,000 t compared with the revised 1999 data (table 9). Mexico (13%) and Mongolia (29%) reported the largest increases.

Canada.—In 2000, Canada imported 19,300 t of metallurgical-grade fluorspar and 161,000 t of acid-grade fluorspar. Total fluorspar imports increased by 6% compared to those of 1999. The major sources of supply were, in descending order, Mexico, Morocco, and China (Jane Currie, Minerals and Mining Statistics Division, Natural Resources Canada, written commun., 2001). The two major fluorspar consumers in Canada are the Honeywell HF plant at Amherstburg, Ontario, and Alcan Aluminium Ltd., which produces AlF_3 at its Vaudreuil refinery at Jonquière, Québec.

The previously announced merger between Canadian companies Burin Fluorspar Ltd. and Blue Desert Mining Inc. was unsuccessful. Shareholders had apparently approved the merger but delays in acquiring regulatory approval and the soft mining sector were given as reasons for the failure. Blue Desert had changed its name to Canada Fluorspar Inc. in anticipation of the expected merger, but Burin Fluorspar and Canada Fluorspar are in no way affiliated. Burin Fluorspar continued its attempts to arrange financing to reopen the mine and mill at St. Lawrence, Newfoundland, and to find a strategic joint-venture partner to take partial ownership in the company (Burin Minerals Ltd., 2000).

China.—Determining China's actual production data for acid- and metallurgical-grade fluorspar has always been difficult owing to the lack of official Government data and the complex nature of the network of producers, processors, exporters, and consumers in China. Problems range from an unreliable breakdown of export data by grade to the lack of reliable information on domestic consumption levels, which may include more than 400,000 t/yr of submetallurgical-grade fluorspar for cement and glass manufacturing.

Although China's fluorspar production and export levels have remained fairly constant, there have been numerous plant and mine closures, openings, and consolidations in recent years resulting in the number of active mills decreasing to about 80 in 2000 from about 125 in 1997. As a result, the distribution of production across China has changed. Zhejiang Province continues to be a major producing area, but smaller producing provinces such as Hubei and Shandong have seen capacity plummet, while the southern provinces of Jujian and Jiangxi have reported dramatic increases in production (Industrial

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Minerals, 2001).

In late 2000, the Chinese Ministry of Foreign Trade and Economic Cooperation held bidding for about 750,000 t of an expected total of 1.15 Mt of fluorspar authorized for export in 2001. There was about 395,000 t released under agreement bids at $39 per ton and 350,000 t under open bid at about $84 per ton. This averaged to about $60 per ton, which was $15 per ton higher than the average in 2000.

European Union.—After a review of the antidumping duties (established in December 1995) on imports of Chinese fluorspar in the form of filtercake or powder into the European Union (EU), the Council of the European Union determined that the duty should be maintained. The duty remains equal to the difference between a minimum price of 113.5 euros per dry ton and the net, free-at-Community-frontier price, before customs clearance (Industrial Minerals, 2000b).

After a 4-month series of conciliation talks between members of the European Parliament and EU Governments, a new timetable for the phaseout of HCFCs in the EU was approved. HCFCs may not be used in new refrigeration equipment after July 1, 2002, and after 2010, virgin HCFCs may not be used, even in existing refrigeration and air-conditioning equipment. Recycled HCFCs may be still be used as an alternative to virgin material from 2010 to 2015, at which time a total ban goes into effect (European Chemical News, 2000).

France.—The merger of Elf Aquitaine S.A. and TotalFina S.A., France's largest oil and gas companies, into the newly-merged group TotalFinaElf S.A., resulted in the reorganization of all chemical activities under the name ATOFINA S.A. Elf Atochem North America, Inc., a major producer of fluorochemicals for the foam blowing and refrigeration markets, was renamed ATOFINA Chemicals, Inc. The company will remain headquartered in Philadelphia, PA (ATOFINA Chemicals, Inc., June 19, 2000, Letter to customers—Elf Atochem North America, Inc., now ATOFINA Chemicals, Inc., accessed July 30, 2000, via URL http://www.atofinachemicals.com/whatsnew/index.cfm?DisplayDate=01/01/2000).

Iran.—Iran first produced fluorspar in 1960 as a byproduct of lead mining, and the first fluorspar mine was developed in 1968. In 2000, there were reportedly 10 active mines, most of which are small and produce only a few thousand tons per year. The largest by far is the Kamar Mehdi Mine, which produces about 20,000 t/yr and is located 165 kilometers southwest of Tabas in Khorassan Province. All of Iran's production is metallurgical grade, much of which is hand sorted, although mechanical sorting is used at Kamar Mehdi on smaller size material. The USGS estimated Iran's 2000 production at 20,000 t, but it may be as high as 40,000 to 50,000 t (Hadavi, 2001).

Mexico.—DuPont announced plans to sell its 32.88% stake in Mexican HF producer Quimica Fluor S.A. de C.V. to Inmuebles Cantabria S.A. de C.V. Quimica Fluor operates at Matamoros, just across the border from Brownsville, TX. The Quimica Fluor plant has a capacity of 86,000 t/yr and produced about 77,000 t of HF in 1999. DuPont had been a shareholder since 1971, but management no longer believed that maintaining an equity interest in Quimica Fluor was necessary to meet its business needs (Industrial Minerals, 2000a).

The Solvay Group, based in Belgium, acquired Mexican HF producer Norfluor S.A. Norfluor manufactures hydrofluoric acid, ammonium fluoride, and ammonium bifluoride at its plant in Ciudad Juárez. The plant's HF capacity is 31,000 t/yr. To reflect the new ownership of the plant, Norfluor's name was changed to Solvay Fluor México, S.A. de C.V. (Industrial Minerals, 2000c).

Russia.—In late 1999, the Government increased import duties on fluorspar to 15% from 5% to make market conditions more favorable to Russian producers. In 2000, however, the largest domestic producer, Yaroslavsky Mining & Dressing Complex (YMDC), reportedly intended to ask the Russian Government to prohibit tenders on delivering foreign fluorspar to Russia. In lieu of this, YMDC believed that the duties should be raised to 30%. In 2000, YMDC increased its production to about 160,000 t (Industrial Minerals, 2000d).

South Africa.—The Buffalo fluorspar mine in South Africa, which shut down in early 1994, was acquired in May 2000 by International Metals Processing (Pty.) Ltd. (IMP). The company overhauled and recommissioned the flotation plant and associated equipment, a project that was completed by the end of October 2000. The company stated that initially they would be processing feed from high-grade stockpiles and tailings dumps. They planned to recommission the briquet plant to process any material that failed to meet the acid-grade standards. Restarting full-scale mining is not expected until 2003, at which time the mine would have reserves sufficient to maintain mine production for 15 years. Sales in the fourth quarter of 2000 were limited and on a spot basis, but IMP worked on marketing its product directly to consumers worldwide (International Metals Processing (Pty.) Ltd., 2000). The product may be excluded from some acid-grade markets, however, because of high phosphorus levels.

When the Buffalo fluorspar mine was closed by General Mining Union Corp. (GENCOR) in 1994, the company gave as the reasons lower world demand and a drop in prices. In GENCOR's opinion these made the mine unprofitable. This was when Chinese acid-grade prices were $65 to $70 per ton, f.o.b. China, or about $95 per ton U.S. Gulf coast. Under these conditions, GENCOR stated they only had 2 years of reserves left. Because the definition of reserves has an economic dimension, fluorspar prices have an effect on reserve estimates. Reserves as measured at a delivered price of $95 per ton would be lower than those measured at $120 per ton.

Vergenoeg Mining Co. (Pty.) Ltd. got approval for its environmental management plan (EMP) from the Department of Minerals and Energy. The EMP considered premining land use, the effect on the environment during mining, the anticipated postmining land use, and the socioeconomic effect of the employment of the local population. After the acquisition of the mine in 1999, partners Metorex (Pty.) Ltd. and Minerales y Productos Derivados S.A. completed a computer model of the ore body; evaluated the existing plant configuration, available equipment, and processing methods; and decided to proceed with long-term capital investment to improve quality and recovery at the mine (Cooke, 2001).

Current Research and Technology

Representatives of Italian fluorochemicals producer Fluorsid S.p.A. and Swedish process equipment manufacturer Svedala Ltd. presented a paper entitled "Recovery of Fluosilicic Acid and Fluoride Bearing Waters for the Production of a Mixture of Silica and Precipitated Calcium Fluoride Usable for the Production of Cement" at the International Fertilizer Industry Association's 2000 Technical Conference in New Orleans. The process, which has been used by Fluorsid for 9 years, involves the treatment of process waters containing HF, H_2SiF_6, HCl, and H_2SO_4 via water treatment and filtration. The process waters

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are initially treated with limestone and then with hydrated lime (calcium hydroxide). A flocculating agent is added, the slurry is clarified, and then sent to a thickener to bring it up to the optimum concentration for filtration (280 to 300 grams per liter). The slurry is pumped into Svedala tube presses, which, under 100-bar pressures, filter out the solids that are discharged in hard, compact flakes 1 to 3 centimeters thick. The product has a composition of CaF_2 (50% to 65%), SiO_2 (9% to 10%), $CaSO_4$ (8% to 10%), $CaCO_3$ (3% to 6%), Al_2O_3 (2% to 3%), Fe_2O_3 (1% to 2%), and $MgCO_3$ (1% to 2%). This product has been found suitable for use in cement manufacturing where a small amount of low-grade fluorspar is added as a flux to reduce the residence time of raw materials in the kiln and thus increase production capacity.

This process was tested to determine its applicability for use in processing fluorosilicic acid from phosphoric acidplants. The tests returned results of CaF_2 (70%), SiO_2 (17%), $CaCO_3$ (6%), Al_2O_3 (1%), and Fe_2O_3 (1%). Although still suitable for the cement market, the high SiO_2 content would likely make it unsuitable for the metallurgical market. Fluorsid believes that the process could be successfully applied to fluorinated muds produced from the processing of phosphate rock (Lavanga and others, 2000).

Outlook

Fluorocarbon production from HF is the single largest market that drives fluorspar demand. Demand for HFC 134 is benefiting from steady auto sales, retrofits, and an emerging aftermarket. In the United States, HFCs and HCFCs used as refrigerants in large cooling chillers are in demand as the conversion from CFC chillers to non-CFC chillers continues. Chillers cool water that is circulated through buildings to air condition factories, hospitals, malls, offices, etc. By the end of 2001, it was expected that about one-half of the 80,000 CFC chillers in operation in the early 1990s would have been converted. The rate of conversion will likely be accelerated because of high electricity prices (new chillers can be 40% more efficient than the units being replaced) and a shrinking supply of CFCs 11 and 12. As an indication of the expected increase in demand, companies have completed or announced capacity increases for HFCs 32, 125, 134a, 227ea, and 245fa in France, Germany, Japan, the United Kingdom, and the United States. There is, however, much uncertainly related to market losses to not-in-kind replacements, tighter recycling requirements in air-conditioning systems that will reduce aftermarket sales, the ban on the foam-blowing agent HCFC 141b in 2003, and potential future restrictions owing to the global warming potential of fluorocarbons. The fluoropolymer and fluoroelastomer markets are growing at an even faster rate, and fluorine compounds such as chlorine trifluoride, nitrogen trifluoride, and tungsten hexafluoride used by the semiconductor industry are in increased demand.

In recent years, the aluminum industry has experienced a 3.3% annual decrease in the consumption of AlF_3. This was the result of better filtering of alumina hydrate to remove Na_2O, an impurity the addition of AlF_3 addresses, and because the new smelters introduced had much lower AlF_3 consumption rates. This trend is expected to reverse itself, especially since the largest increases in aluminum production are expected to be in China and the Commonwealth of Independent States (C.I.S.), which will continue using older smelters. Considering only that portion of AlF_3 demand supplied by fluorspar, based on estimates of relative aluminum production growth for China, C.I.S, and the West, the demand for fluorspar in this market may increase by as much as 15,000 to 17,000 t/yr through 2004. The largest portion of this increase is expected to occur in China and the C.I.S. In the longer term, new smelting technologies could lower fluorspar demand significantly. Widespread adoption of the new Kvaerner Process Technology fluorosilicic acid/HF process, which can be used to manufacture AlF_3 as a byproduct of phosphoric acid production, could conceivably replace the production of AlF_3 from fluorspar (Reynolds, 2001).

The domestic steel industry is plagued by high levels of imports, large inventories, and bankruptcies; the slowing economy will only exacerbate the industry's problems. Through the middle of June 2001, domestic steel production was 13% lower than that in the same period in 2000. These factors are expected to cause an estimated 10% decrease in U.S. steel production in 2001, and fluorspar sales for steel are likely to decrease by a similar amount. The economic slowdown will have a similar effect, although probably not as large, on other small merchant markets. In the long term, growth is still expected in the cement market. Some cement manufacturers are starting to use fluorspar in clinker production. Fluorspar can be added to limestone in the cement kiln as a fluxing agent, where it reduces the residence time and increases production capacity.

References Cited

Burin Minerals Ltd., 2000, Progress report: St. Lawrence, NF, Burin Minerals Ltd. press release, September 30, 1 p.

Chemical Market Reporter, 2000, Honeywell plans HFC plant: Chemical Market Reporter, v. 257, no. 14, April 3, p. 3.

Cooke, Dennis, 2001, Maximizing Vergenoeg's potential—2001 and beyond, *in* Industrial Minerals Fluorspar 2001 Conference, Johannesburg, March 25-27, Proceedings: London, Industrial Minerals, [unpaginated].

European Chemical News, 2000, Phase-out deadline agreed: European Chemical News, v. 72, no. 1915, June 26-July 2, p. 45.

Hadavi, M.A., 2001, Iranian fluorspar—An emerging force, *in* Industrial Minerals Fluorspar 2001 Conference, Johannesburg, March 25-27, Proceedings: London, Industrial Minerals, [unpaginated].

Industrial Minerals, 2000a, DuPont sells Quimica Fluor stake: Industrial Minerals, no. 395, August, p. 23.

———2000b, EC to uphold duties on Chines fluorspar: Industrial Minerals, no. 398, November, p. 11.

———2000c, Solvay expands in fluorochemicals: Industrial Minerals, no. 389, February, p. 14.

———2000d, Yaroslavsky GOK demands fluorspar import protection: Industrial Minerals, no. 393, June, p. 23.

———2001, Sandton safari—The big game of fluorspar: Industrial Minerals, no. 404, May, p. 34.

International Metals Processing (Pty.) Ltd., 2000, Buffalo fluorspar mine: South Africa, International Metals Processing (Pty.) Ltd. press release, December 5, 2 p.

Lavanga, Michele, Di Lena, Sergio, Sullivan, Shane, and Ingram, Alan, 2000, Recovery of fluosilicic acid and fluoride bearing waters for the production of a mixture of silica and precipitated calcium fluoride usable for the production of cement, *in* International Fertilizer Industry Association Technical Conference, New Orleans, October 1-4, 2000, Proceedings: Paris, International Fertilizer Industry Association, [unpaginated].

Reynolds, M.S., 2001, Fluorspar in the aluminium industry—Past, present, and future, *in* Industrial Minerals Fluorspar 2001 Conference, Johannesburg, March 25-27, Proceedings: London, Industrial Minerals, [unpaginated].

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Fluorine. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Fluorspar. Ch. in Mineral Commodity Summaries, annual.

Fluorspar. Ch. in Minerals Yearbook, annual.

Digitized by Google

Fluorspar. Mineral Industry Surveys, quarterly.
Geology and Resources of Fluorine in the United States, Professional Paper 933, 1976.

Other

Chemical and Engineering News.
Chemical Market Reporter.
Chemical Week.
The Economics of Fluorspar. Roskill Information Services Ltd., 1993.
European Chemical News.
Fluorspar. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Fluorspar. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675.
Industrial Minerals (London).
North American Minerals News.
Fluorine. Chemical Economics Handbook, SRI International.
U.S. Department of Commerce Current Industrial Reports, Inorganic Chemicals, MQ325A.

TABLE 1
SALIENT FLUORSPAR STATISTICS 1/ 2/

		1996	1997	1998	1999	2000
United States:						
Production, finished (shipments) e/	metric tons	8,200	--	--	--	--
Production, value, free on board mine	thousand dollars	W	--	--	--	--
Exports 3/	metric tons	61,600	62,100	23,600	55,400	39,800
Value 4/	thousands	$8,110	$8,330	$3,890	$6,970	$5,330
Imports: 3/	metric tons	513,000	538,000	503,000	478,000	523,000
Value 5/	thousands	$71,000	$69,500	$62,700	$56,900	$65,200
Value per ton, acid grade 5/		$142.00	$134.00	$128.00	$124.00	$128.00
Value per ton, metallurgical grade 5/		$103.00	$90.70	$89.20	$87.80	$84.30
Consumption:						
Reported	metric tons	527,000	491,000	538,000	515,000	512,000
Apparent 6/	do.	719,000	551,000	591,000	615,000	601,000
Stocks, December 31:						
Consumer and distributor 7/	do.	234,000	375,000	468,000	373,000	289,000
Government stockpile	do.	667,000	448,000	243,000	146,000	112,000
World, production	do.	4,040,000 r/	4,170,000 r/	4,370,000 r/	4,420,000 r/	4,520,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits.
2/ Does not include fluorosilicic acid (H_2SiF_6) or imports of hydrofluoric acid (HF) and cryolite.
3/ Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.
4/ Free alongside ship values at U.S. ports.
5/ Cost, insurance, freign values at U.S. ports.
6/ U.S. primary and secondary production plus imports minus exports plus adjustments for Government and industry stock changes.
7/ Includes fluorspar purchased from the national defense stockpile, but still located at national defense stockpile depots.

TABLE 2
U.S. REPORTED CONSUMPTION OF FLUORSPAR, BY END USE 1/

(Metric tons)

	Containing more than 97% CaF_2		Containing not more than 97% CaF_2		Total	
End use or product	1999	2000	1999	2000	1999	2000
Hydrofluoric acid and aluminum fluoride	469,000	474,000	1,220	16	470,000	474,000
Basic oxygen furnaces	--	--	9,590	8,600	9,590	8,600
Electric furnaces	W	W	8,780	7,270	8,780	7,270
Other 2/	14,300	13,600	11,600	8,650	25,900	22,200
Total	483,000	487,000	31,200	24,500	515,000	512,000
Stocks (consumer), December 31	65,400	48,300	25,200	25,700	90,500	73,900

W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes enamel, glass and fiberglass, iron and steel foundries, primary aluminum, primary magnesium, and welding rod coatings.

TABLE 3
PRICES OF IMPORTED FLUORSPAR

Source-grade		1999	2000
Mexican, free on board (f.o.b.) Tampico:			
Acidspar filtercake	dollars per metric ton	110-130	110-130
Metallurgical grade	do.	85-105	85-105

See footnotes at end of table.

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TABLE 3--Continued
PRICES OF IMPORTED FLUORSPAR

Source-grade		1999	2000
Mexican, f.o.b. Mexico, acidspar filtercake, As <5 ppm	dollars per metric ton	130-140	132-145
South African, acidspar dry basis, f.o.b. Durban	do.	105-125	105-125
U.S. Gulf port, dry basis, acidspar	do.	127-138	130-135

Sources: Industrial Minerals, no. 387, p. 70, December 1999; and no. 399, p. 74, December 2000.

TABLE 4
U.S. EXPORTS OF FLUORSPAR, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value 2/	Quantity (metric tons)	Value 2/
Canada	24,400	$3,900,000	18,100	$2,930,000
Dominican Republic	104	18,900	62	9,090
Italy	27,800	2,540,000	13,200	1,210,000
Korea, Republic of	3	3,120	--	--
Mexico	136	40,800	4,520	441,000
Taiwan	1,990	278,000	3,310	592,000
United Kingdom	62	11,900	--	--
Other 3/	845	178,000	647	146,000
Total	55,400	6,970,000	39,800	5,330,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Free alongside ship values at U.S. ports.
3/ Includes Australia, Belgium, France, Germany, India, Ireland, Japan, the Netherlands, Papua New Guinea, Saudi Arabia, Spain, Sweden, Switzerland, and Venezuela.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT 1/

	1999		2000	
Country and customs district	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Containing more than 97% calcium fluoride (CaF_2)				
Austria, Charleston	107	$63	--	--
China:				
Houston	179,000	22,400	183,000	$23,200
New Orleans	108,000	13,400	145,000	19,800
Total	287,000	35,900	328,000	43,000
France, Philadelphia	163	67	204	80
Germany:				
Boston	--	--	112	14
Philadelphia	--	--	172	20
Savannah	291	53	68	37
Total	291	53	352	71
Kenya, Laredo	--	--	18	3
Mexico:				
Detroit	204	38	71	12
El Paso	1	3	--	--
Laredo	17,300	2,130	17,700	2,350
New Orleans	--	--	3,900	378
Total	17,500	2,170	21,700	2,740
South Africa:				
Houston	23,700	2,890	42,600	5,020
New Orleans	90,000	10,600	91,200	11,000
Total	114,000	13,500	134,000	16,000
United Kingdom:				
New York City	13	21	15	28
Los Angeles	95	13	182	23
Total	108	33	197	51
Grand total	419,000	51,800	484,000	62,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT 1/

Country and customs district	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Containing not more than 97% CaF_2				
Canada, Buffalo	97	$29	21	$6
China:				
New Orleans	16,700	1,500	--	--
Ogdensburg	9	4	--	--
Total	16,700	1,500	--	--
Mexico:				
Laredo	4,400	374	2,430	201
New Orleans	37,500	3,250	36,300	3,040
Total	41,900	3,620	38,700	3,240
United Kingdom, Philadelphia	--	--	6	17
Grand total	58,700	5,150	38,700	3,260
Total imports all grades	478,000	56,900	523,000	65,200

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID, BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Canada	26,800	$31,000	36,000	$41,100
China	17	14	144	99
France	343	374	212	209
Germany	147	349	150	285
Japan	1,440	4,150	1,670	4,590
Korea, Republic of	--	--	80	329
Mexico	91,200	83,700	92,400	84,500
United Kingdom	38	40	163	189
Total	120,000	120,000	131,000	131,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF CRYOLITE, BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Australia	2,490	$1,410	2,140	$1,220
Canada	1,960	527	2,840	1,090
China	442	356	398	323
Denmark	222	355	76	119
Germany	2,700	2,810	2,770	2,840
Hungary	391	428	439	495
Japan	17	16	20	19
New Zealand	557	405	--	--
Spain	323	281	--	--
United Kingdom	294	419	333	486
Other 3/	172	143	174	131
Total	9,560	7,160	9,190	6,730

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Cost, insurance, and freight values at U.S. ports.
3/ Includes Austria, Belgium, Hong Kong, India, Italy, and Russia.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM FLUORIDE, BY COUNTRY 1

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Canada	5,330	$4,500	3,610	$3,080
Italy	--	--	2,880	2,000
Mexico	11,100	9,340	11,600	9,550
Norway	2,800	2,620	2,580	2,020
Other 3/	151	248	763	647
Total	19,300	16,700	21,500	17,300

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Cost, insurance, and freight values at U.S. ports.

3/ Includes China, Finland, Germany, India, Israel, Japan, and Sweden.

Source: U.S. Census Bureau.

TABLE 9
FLUORSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country and grade 3/ 4/	1996	1997	1998	1999	2000 e/
Argentina	5,666	7,168	7,200 e/	7,000 e/	7,000
Brazil (marketable):					
Acid grade	46,706	66,859	61,024	61,000 e/	61,000
Metallurgical grade	12,334	11,174	11,058	11,000 e/	11,000
Total	59,040	78,033	72,082	72,000 e/	72,000
China: e/					
Acid grade	1,250,000	1,150,000	1,180,000	1,200,000	1,250,000
Metallurgical grade 5/	900,000	1,150,000	1,170,000	1,200,000	1,200,000
Total	2,150,000	2,300,000	2,350,000	2,400,000	2,450,000
Egypt e/	700	775 r/	140 r/	500 r/	500
France: e/					
Acid and ceramic grades	78,000 6/	80,000	80,000	82,000	80,000
Metallurgical grade	33,000 6/	30,000	30,000	25,000	20,000
Total	111,000 6/	110,000	110,000	107,000	100,000
Germany e/	32,448 6/	24,000	25,000	28,000	30,000
India:					
Acid grade	5,115	6,937	-- e/	-- e/	-- 6/
Metallurgical grade	14,263	9,877	785 6/	800 e/	850 6/
Total	19,378	16,814	785 6/	800 e/	850 6/
Iran 7/	20,000	20,000 e/	25,904 r/	18,387 r/	20,000
Italy: e/					
Acid grade	103,527 6/	106,000	92,000	95,000	50,000
Metallurgical grade	23,000 6/	20,000	15,000	15,000	15,000
Total	126,527 6/	126,000	107,000	110,000	65,000
Kenya, acid grade	83,000	68,700	60,854	98,000 e/	90,000
Korea, North, metallurgical grade e/	39,000	39,000	30,000	25,000	25,000
Korea, Republic of, metallurgical grade e/	--	617 6/	--	--	--
Kyrgyzstan	2,767	4,176	3,200 e/	2,997	3,000
Mexico: 8/					
Acid grade	279,033	290,580	330,711	324,741 r/	350,000
Metallurgical grade	244,938	262,260	267,331	236,524 r/	285,000
Total	523,971	552,840	598,042	561,265 r/	635,000
Mongolia:					
Acid grade	130,000	130,000	122,000	100,000 r/	111,443 6/
Other grades 9/	37,000	41,000	45,900 r/	54,600 r/	87,400 6/
Total	167,000	171,000	167,900 r/	154,600 r/	198,843 6/
Morocco, acid grade	95,900	103,800	110,000 e/	110,000 e/	100,000
Namibia, acid grade 10/	32,285	23,208	40,685	57,700 r/	58,000
Pakistan, metallurgical grade	363	1,050	1,000 e/	220	700
Romania, metallurgical grade e/	15,000	15,000	15,000	15,000	15,000
Russia e/	40,000 r/	8,000 r/	120,000 r/	155,000 r/	160,000
South Africa: e/ 11/					
Acid grade	191,018 6/	201,000	222,000	203,280 r/ 6/	197,855 6/
Ceramic grade	-- 6/	4,000	--	--	--

See footnotes at end of table.

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TABLE 9--Continued
FLUORSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country and grade 3/ 4/	1996	1997	1998	1999	2000 e/
South Africa--Continued: e/ 11/					
Metallurgical grade	12,000	2,000	15,000	14,000	14,500
Total	205,014 6/	208,997 6/	238,998 6/	219,279 6/	212,355 6/
Spain: e/					
Acid grade	109,085 6/	110,000	110,000	123,000	115,000
Metallurgical grade	7,441 6/	10,000	10,000	10,000	10,000
Total	116,526 6/	120,000	120,000	133,000	125,000
Tajikistan e/	9,000	9,000	9,000	9,000	9,000
Thailand, metallurgical grade	17,247	7,826	3,743	13,005 r/	4,745 6/
Tunisia	720	1,426	1,196	520	-- 6/
Turkey, metallurgical grade e/	4,828 6/	5,000	5,000	5,000	5,000
United Kingdom e/	65,000	64,000	65,000	42,000	45,000
United States (shipments) e/	8,200	--	--	--	--
Uzbekistan e/	90,000	90,000	80,000	80,000	80,000
Grand total	4,040,000 r/	4,170,000 r/	4,370,000 r/	4,420,000 r/	4,520,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 1, 2001.

3/ In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

4/ An effort has been made to subdivide production of all countries by grade (acid, ceramic, and metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.

5/ Includes submetallurgical-grade fluorspar used primarily in cement that may account for 33% to 50% of the quantity.

6/ Reported figure.

7/ Year beginning March 21 of that stated.

8/ Data are reported by Consejo de Recursos Minerales, but the production of submetallurgical and acid grades has been redistributed on the basis of industry data.

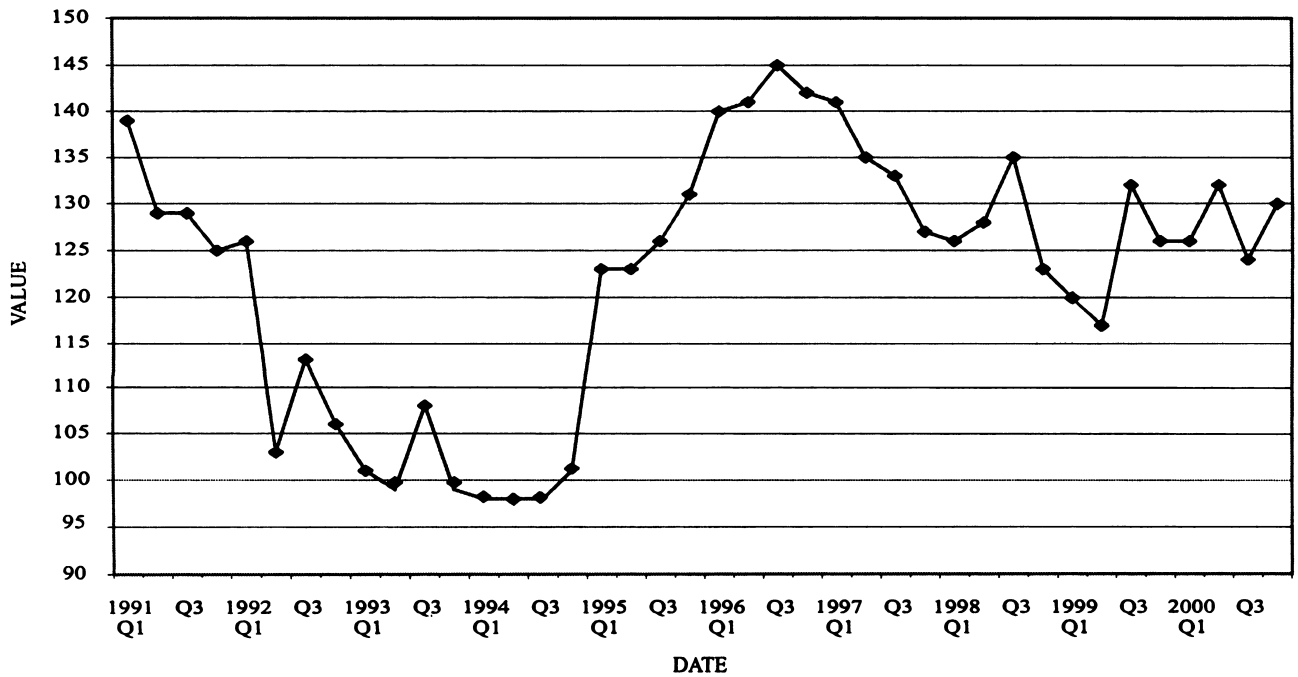
9/ Principally submetallurgical-grade material.

10/ Data are in wet tons.

11/ Based on data from the South African Minerals Bureau, data show estimated proportions of acid-, ceramic-, and metallurgical-grade fluorspar within the reported totals.

FIGURE 1
ACID-GRADE FLUORSPAR IMPORT PRICES BY QUARTER

(Dollars per metric ton, c.i.f. port of entry, Q=quarter)



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GALLIUM

By Deborah A. Kramer

Domestic survey data and tables were prepared by Carolyn F. Crews, statistical assistant.

By yearend, worldwide gallium supplies were insufficient to meet consumption rates. Free market gallium prices skyrocketed to reach $1,500 to $2,000 per kilogram, a level not seen since the early 1960s when technologic improvements in gallium recovery processes brought down the price from $3,000 per kilogram.

Gallium demand in the United States was met by imports, primarily high-purity material from France and low-purity material from Kazakhstan. More than 95% of the gallium consumed in the United States was in the form of gallium arsenide (GaAs). Analog integrated circuits (ICs) were the largest application for gallium, with optoelectronic devices [mostly laser diodes and light-emitting diodes (LEDs)] as the second largest end use. U.S. GaAs manufacturers completed many of their capacity expansions that had been announced earlier and continued planning additional capacity expansions. Many of these expansions involved conversions from 4-inch wafer processing capacity to 6-inch capability, which is considered the next plateau in GaAs processing ability. Growth in the wireless communications industry was cited as the principal driving force behind most of the GaAs production expansions.

World production of virgin gallium was estimated to be 90 metric tons (t). Total demand for refined gallium, however, was estimated to be 120 t and was centered in Japan, the United States, and Western Europe. Significant quantities of new scrap were recycled and supplemented supplies, particularly in Japan.

Production

No domestic production of primary gallium was reported in 2000 (table 1). Eagle-Picher Industries Inc. recovered and refined gallium from domestic and imported sources at its plant in Quapaw, OK. Recapture Metals Inc. in Blanding, UT, recovered gallium from scrap materials, predominantly those generated during the production of GaAs. Recapture Metals facilities have the capability to process about 17 metric tons per year (t/yr) of high-purity gallium. The company recovered gallium from its customers' scrap on a fee basis and purchased scrap and low-purity gallium for processing into high-purity material.

Consumption

More than 95% of the gallium consumed in the United States was in the form of GaAs. GaAs was manufactured into optoelectronic devices (LEDs, laser diodes, photodetectors, and solar cells) and ICs. Analog ICs were the largest end-use application for gallium, with 63% of total consumption. Optoelectronic devices accounted for 32% of domestic consumption, and the remaining 5% was used in digital ICs, research and development, and other applications (tables 2, 3).

Gallium consumption data are collected by the U.S. Geological Survey from one voluntary survey of U.S. operations. In 2000, there were 13 responses to the consumption of gallium survey, representing 59% of the total canvassed. Because of the poor response rate, data in tables 2 and 3 were adjusted by incorporating estimates to reflect full industry coverage.

Projected growth in GaAs components for wireless applications led to the completion of several new GaAs manufacturing facilities and announcements of more expansions. In 2000, M/A-Com Inc., Lowell, MA, completed an expansion of its GaAs wafer fabrication capacity, adding a new high-volume 6-inch wafer manufacturing line. The expansion resulted from a multiyear agreement with Sanders Corp., based in Nashua, NH, in which M/A-Com will use existing capacity and equipment at the Sanders facility to

Gallium in the 20th Century

Although gallium had been discovered in 1875, it was not produced in the United States until 1915, and commercial-scale recovery did not begin until 1943. Until 1960, gallium had very limited uses. Most of its consumption was for experimental purposes; small quantities were used as a specialized mirror coating, in high-temperature thermometers, and in low-melting-point metal alloys. Although few statistical data are available, U.S. demand for gallium was considered negligible (fewer than 50 kilograms) until 1965. Introduction of the gallium-arsenide-based light-emitting diode (LED) changed the consumption pattern of gallium from that of a laboratory curiosity to a metal with some consumer applications. LEDs, used in such applications as displays in digital watches and hand-held calculators, were responsible for large annual increases in consumption from the mid-1960s until the mid-1970s. Gallium consumption continued to grow throughout the remainder of the century as new uses were developed.

By 2000, the consumption of gallium in the United States had reached nearly 40 metric tons. Almost all of this was for gallium arsenide components in electronic applications. LEDs remained in widespread use for many electronic displays, including window brake lights in automobiles. Gallium-arsenide-based laser diodes were used in such items as CD and DVD players, and gallium-arsenide-based integrated circuits were used in sophisticated military radars. Scientists continue to investigate gallium's properties, which may lead to the development of new applications for gallium. As a result, growth in gallium consumption was expected to continue well into the 21st century.

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manufacture monolithic microwave integrated circuits (MMICs) on 6-inch GaAs wafers for wireless and telecommunications markets. Sanders will continue to manufacture MMICs at the same facility for aerospace and defense applications. The new manufacturing line is expected to be operational by the first half of 2001 (GaAsNet, June 8, 2000, M/A-Com doubles GaAs fab capacity, adds six-inch wafer line, accessed June 9, 2000, at URL http://www.gaasnet.com/news/macom_08062000.html). In March, M/A-Com completed the acquisition of the GaAsTEK subsidiary of ITT Corp., Roanoke, VA, which manufactures GaAs MMICs for defense industries (M/A-Com Inc., March 7, 2000, M/A-Com completes GaAsTEK acquisition, accessed March 30, 2000, at URL http://www.macom.com/about/press.asp?ID=35). This acquisition, along with the use of the Sanders facilities, gives M/A-Com four GaAs manufacturing facilities in the United States—Colorado Springs, CO; Lowell, MA; Nashua, NH; and Roanoke, VA.

In March, EMCORE Corp. completed the first phase of an expansion at its Somerset, NJ, GaAs manufacturing facility to meet increased demand for the company's heterojunction bipolar transistor (HBT) and pseudomorphic high-electron-mobility transistor (pHEMT) products; this phase doubled the company's capabilities to produce 4- and 6-inch wafers. In August, EMCORE completed a second expansion that again doubled its GaAs wafer production capacity. The first phase of the expansion added 186 square meters (m^2) of production space, which accommodated six additional epitaxial production machines. The second phase, consisting of 650 m^2, will accommodate 10 metal-organic chemical vapor deposition (MOCVD) production tools, to bring the total to 18, allowing a total annual production capacity of 360,000 6-inch wafers (EMCORE Corp., March 2, 2000, EMCORE nearly doubles production capacity for GaInP HBTs and pHEMTs to meet wireless and fiber optic market demands, accessed November 30, 2000, at URL http://www.emcore.com/html_documents/News_clips/2000/doubles_capacity.htm; GaAsNet, August 2, 2000, EMCORE completes expansion of NJ manufacturing facility, increasing capacity by 400%, accessed August 9, 2000, at URL http://www.gaasnet.com/news/emcore_02082000.html). The company also plans to triple production capacity at its EMCORE West site in Albuquerque, NM, that houses its solar cell, optical component, and networking products. The expansion will add 3,300 m^2 of capacity to the existing 4,640-m^2 facility. Completion was scheduled for yearend 2000 (GaAsNet, June 8, 2000, EMCORE plans to significantly expand Sandia Technology Park site, accessed June 9, 2000, at URL http://www.gaasnet.com/news/emcore_08062000.html).

In October, Kopin Corp. completed a 5,500-m^2 facility near its headquarters in Taunton, MA, that is expected to generate about 40% of the company's GaAs HBT business. The new facility was expected to be operational by the first quarter of 2001. As part of the expansion, Kopin ordered six HBT systems from AIXTRON AG to be delivered in the first quarter of 2001. After delivery of the new systems, Kopin will have a total of 22 machines—8 capable of handling multiple 4-inch HBTs and 14 that can handle 6-inch HBTs. Total annual production capacity will be more than 400,000 4-inch and 200,000 6-inch wafers (GaAsNet, May 16, 2000, Kopin establishes second site for HBT production, accessed June 9, 2000, at URL http://www.gaasnet.com/news/kopin_16052000.html; GaAsNet, June 11, 2000, Kopin Corporation orders six additional HBT systems from AIXTRON, accessed June 21, 2000, at URL http://www.gaasnet.com/news/kopin_11062000.html). Also in October, Kopin acquired privately held Super Epitaxial Products Inc., which conducted research and development on optoelectronic materials. Kopin believes that the acquired mix of products, combined with its technical expertise, will allow the company to provide components for existing and emerging optical communications applications. Under the terms of the agreement, 1.7 million shares of Kopin stock with an estimated value of $25 million were exchanged for all of the outstanding shares of Super Epitaxial Products (GaAsNet, October 31, 2000, Kopin acquires Super Epitaxial Products to add opto wafers, accessed October 31, 2000, at URL http://www.gaasnet.com/news/kopin_31102000.html).

ATMI Inc. (formerly Epitronics Corp.) planned to increase production capacity at its Phoenix, AZ, facility by constructing a 4,640-m^2 facility that will contain 11 AIXTRON metal-organic vapor phase epitaxy (MOVPE) reactors and will have space for 8 more. The expansion is in response to growing wireless telecommunications applications. In addition, ATMI is expanding its development of gallium nitride (GaN) wafers for blue laser diodes. The company has developed and patented a process for growing high-purity GaN wafers 50 millimeters (mm) in diameter and, based on this success, has been awarded a U.S. defense industry contract to develop the GaN wafer production capabilities further (GaAsNet, October 23, 2000, A T M I announces major HBT capacity expansion, accessed October 31, 2000, at URL http://www.gaasnet.com/news/ATMI_23102000.html).

In September, TriQuint Semiconductor Inc. purchased a wafer fabrication facility in Richardson, TX, from Micron Technology LLC for $87 million. The new facility will allow TriQuint to relocate its current Texas operation from leased space within 2 years. The company planned to install new 6-inch wafer fabrication lines that would duplicate the ones in its Hillsboro, OR, facility first, then relocate its Texas operations to the new facility. By the time the new installation, relocation, and reconfiguration are complete, the new facility will have greater capacity than the company's combined Texas and Oregon capacity (GaAsNet, September 6, 2000, TriQuint Semiconductor completes purchase of Richardson fabrication facility, accessed September 21, 2000, at URL http://www.gaasnet.com/news/triquint_06092000.html).

Sumitomo Electric Industries Ltd. announced that it would construct its first U.S. plant to produce semiconductor materials. The new plant, which will be sited in Hillsboro, OR, will initially focus on GaAs wafers for the wireless communications market and have a production volume of 20,000 wafers per month by 2002. A U.S. location would allow Sumitomo Electric Industries to meet the needs of some of its larger customers in the Western United States, such as TriQuint, TRW Inc., and Motorola Inc; 50% of Sumitomo Electric Industries' market was estimated to be in North America. The new facility also will serve as the company's U.S. headquarters. A new 12,000-m^2 GaAs production plant in Kobe, Japan, which was scheduled to be completed by July 2001, will supply 5-inch wafers to the new U.S. plant (Paul Kallender, Electronic Engineering Times, December 19, 2000, Sumitomo adds U.S. fab to GaAs expansion plans, accessed April 6, 2001, at URL http://www.eetasia.com/ART_8800066750_499481,590626.HTM).

AXT Inc. (formerly American Xtal Technology Inc.) announced that it would triple its GaAs substrate production

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capacity by the end of the third quarter of 2001. Most of the expansion will be in Beijing, China, where the company operates a 5,750-m^2 facility for GaAs production and has purchased a 3,340-m^2 building adjacent to this facility. If AXT can acquire additional nearby buildings, it plans to increase its total capacity to 14,800 m^2. AXT also planned a 1,850-m^2 expansion at its Fremont, CA, plant in 2001 (AXT Inc., May 3, 2000, American Xtal Technology announces a 3x expansion of its GaAs substrate capacity by Q301, accessed February 8, 2001, at URL http://www.axt.com/050300.htm). The company also planned to discontinue its laser diode and consumer product lines in 2001 to concentrate on its core products—high-brightness LEDs and vertical cavity surface-emitting lasers (VCSELs).

ANADIGICS Inc. planned to add cleanroom space and equipment to nearly double its 6-inch indium gallium phosphide (InGaP) HBT, pHEMT, and metal semiconductor field effect transistor (MESFET) production capability. The $10 million expansion, which began in response to an increased demand for the company's wireless and broadband communications products, would link directly with ANADIGICS' existing production line at its Warren, NJ, facility. The completion was scheduled for the beginning of 2001 (GaAsNet, January 16, 2000, ANADIGICS announces plans to expand 6-inch manufacturing operation, accessed January 21, 2000, at URL http://www.gaasnet.com/news/anadigics_16012000.html).

Agilent Technologies Inc. planned to construct a new 6-inch GaAs wafer fabrication facility in Ft. Collins, CO, to produce enhancement-mode pHEMTs for handsets for mobile phones. The first phase of the project, which was scheduled to be completed by the end of 2002, will include 1,400 m^2 of cleanroom that can process 48,000 6-inch wafers per year. Until the new facility is completed, Agilent plans to produce the devices in its existing Santa Clara, CA, facility (Agilent Technologies Inc., October 18, 2000, Agilent Technologies plans six-inch wafer production fab for breakthrough E-pHEMT process, accessed November 30, 2000, at URL http://www.agilent.com/about/newsroom/presrel/2000/18oct2000a.html). Agilent ordered three molecular beam epitaxy (MBE) systems from Thermo VG Semicon Ltd. for its new facility.

Conexant Systems Inc. completed an expansion of its GaAs manufacturing facilities in Newbury Park, CA, in April. Conexant invested $80 million in capital equipment to increase its annual capacity to 95,000 4-inch wafer starts from 15,000. The new manufacturing facilities can be upgraded to 6-inch wafer capability; this conversion will increase capacity to the equivalent of 210,000 4-inch wafer starts per year. Conexant planned to use most of its expanded capacity to manufacture GaAs HBT amplifiers for the digital cellular handset market, and a small portion would be used to manufacture GaAs-HBT-based transceivers for optical communications (Conexant Systems Inc., April 10, 2000, Conexant increases manufacturing capacity five-fold for wireless communications and optical networking products, accessed April 25, 2000, via URL http://www.conexant.com).

Motorola tripled the capacity of its GaAs wafer fabrication facility in June by converting from 4-inch to 6-inch wafer capabilities and equipping the facility to its fullest capacity. The company also purchased MOCVD equipment from EMCORE for the expanded facility. This is one of the first facilities to be fully converted to 6-inch wafer capability for all GaAs technologies—MESFETs, pHEMTs, and HBTs (GaAsNet, June 16, 2000, Motorola Semiconductor completes six-inch conversion of GaAs fab three months ahead of schedule, accessed June 21, 2000, at URL http://www.gaasnet.com/news/motorola_16062000.html).

Intelligent Epitaxy Technology, Inc. (IntelliEPI), Richardson, TX, announced that it had raised $25 million in funding, which would be used to expand its production capacity. IntelliEPI planned to acquire 2,040 m^2 of additional cleanroom space and purchase four additional 6-inch multiwafer MBE systems (GaAsNet, October 14, 2000, Intelligent Epitaxy Technology, Inc. successfully raises $25 million, accessed October 31, 2000, at URL http://www.gaasnet.com/news/ie_13102000.html).

TECSTAR Inc., a Newport Beach, CA, manufacturer of solar cells, announced the formation of a new optoelectronics products organization to meet the growing demand for epitaxial wafers used in high-brightness LEDs and related optoelectronics devices. TECSTAR operated a GaAs MOCVD foundry at its Applied Solar Division. This division's facilities became available in the first quarter of 2000 to support manufacturers of high- and ultrahigh-brightness LED devices and lamps (Compound Semiconductor, January 13, 2000, TECSTAR announces formation of new optoelectronics product group, accessed April 10, 2001, via URL http://www.compoundsemiconductor.net). One of the companies that signed a long-term supply agreement with TECSTAR for use of its MOCVD production capacity was Advanced Photonics Ltd. of Shanghai, China.

TRW signed an agreement with Endgate Corp. to merge its subsidiary TRW Milliwave Inc. and create a new company, Endwave Corp. TRW manufactures transceiver modules that use GaAs MMICs for broadband systems, and Endgate manufactures transceivers, antennas, and outdoor units that enable high-speed wireless telecommunications links. The combination of these two entities into one single company will vertically integrate the production of the devices and include a long-term GaAs supply agreement with TRW. After the merger was completed, Endwave was owned about 53% by TRW and 47% by Endgate. The new firm will be headquartered in Sunnyvale, CA, and will maintain manufacturing and design facilities in Sunnyvale, Santa Clara, and Diamond Springs, CA. In July, Endwave filed an initial public offering to raise $115 million to be used for general corporate purposes and working capital (GaAsNet, March 14, 2000, TRW and Endgate announce merger forming Endwave Corporation, accessed March 14, 2000, at URL http://www.gaasnet.com/news/trw_05032000.html; GaAsNet, July 16, 2000, Radio frequency products firm Endwave files IPO, accessed August 9, 2000, at URL http://www.gaasnet.com/news/endwave_16072000.html).

Prices

In 2000, producer-quoted prices for high-purity gallium were the same as those at yearend 1999 (table 4). Quoted prices, however, do not reflect the actual price trends that occurred during the year. According to Mining Journal, prices remained relatively stable during the first three-quarters of the year, with prices for 99.9999%-pure to 99.99999%-pure material remaining at $500 to $600 per kilogram (Mining Journal, 2000). With a severe shortage of supply in the latter part of 2000, free market prices for gallium skyrocketed, with price levels of up to $1,500 per kilogram being reported by yearend (Mining Journal, 2001).

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Foreign Trade

U.S. gallium imports increased by 64% from those in 1999 (table 5). France (63%), Kazakhstan (12%), Russia (5%), and the United Kingdom (5%) were the principal sources of imported gallium. In addition to gallium metal, GaAs wafers were imported into the United States. In 2000, 31,500 kilograms (kg) of undoped GaAs wafers was imported, an increase of 47% from that in 1999. Lebanon (59%) and Japan (40%) were the principal sources. [Material identified as shipped from Lebanon probably was transshipped, and the country of origin is misidentified, because Lebanon does not produce GaAs wafers.] Japan (31%), the Republic of Korea (21%), and Taiwan (15%) were the main import sources for doped GaAs wafers, totaling 296,000 kg during the year, a decrease of 5% from that in 1999. Quantities of GaAs wafers reported by the U.S. Census Bureau may include the weight of the packaging material and thus may be overstated.

World Review

Estimated crude gallium production was 90 t in 2000. Principal world producers were Germany, Japan, Kazakhstan, and Russia. China, Hungary, Slovakia, and Ukraine also recovered gallium. Refined gallium production was estimated to be about 120 t; this included some new scrap refining. France was the largest producer of refined gallium using gallium produced in Germany as feed material. Japan and the United States also refined gallium. Gallium was recycled from new scrap in Germany, Japan, the United Kingdom, and the United States.

World demand for gallium was forecast to be 210 t in 2000 by Dowa Mining Co. Ltd.; this figure included significant quantities of recycled gallium scrap. Regional demand was estimated to be as follows: Japan, 140 t; the United States, 49 t; Europe, 13 t; and other countries, 8 t. Dowa Mining projected that demand in 2001 would increase to 243 t (Roskill's Letter from Japan, 2001).

Strategies Unlimited estimated that the world market for compound semiconductors (mostly based on GaAs components) reached $18 billion in 2000, an increase of 60% from that in 1999. Optoelectronics had the largest share of the compound semiconductor market, with 80% of the total. Of the optoelectronics market, 60% was for communications applications, 16% for lamps and displays, and 24% for other applications (Hausken, 2001).

China.—The Institute of Semiconductors, which was a part of the Chinese Academy of Sciences, and four other companies signed an agreement in September to commercialize the Institute's semi-insulating GaAs technology. Under the agreement, Compound Crystal Technology Co. Ltd. would be set up by the five entities with capitalization of 100 million yuan (Y) (about $12 million), including technology valued at Y30 million (about $3.6 million). The five entities planned to invest Y300 million to Y400 million (about $36 million to $48 million) in importing production equipment and building a plant. The planned plant, the only one of its kind in China, was expected to produce single-crystal and epitaxial wafers of semi-insulating GaAs (Compound Semiconductor, September 5, 2000, Chinese firms establish venture to commercialize GaAs technology, accessed April 9, 2001, via URL http://www.compoundsemiconductor.net).

France.—Picogiga SA announced that it would double its capacity to produce epitaxial wafers at its Courtaboeuf plant by 2001. The company ordered three MBE reactors from Riber S.A. in July, two MBE reactors from Thermo VG Semicon in September, and three MBE reactors from Applied Epi Inc. in November. Five of the new reactors can process seven 6-inch wafers at a time, instead of four, which was the existing standard. Picogiga planned to allocate specific reactors to the fabrication of HBT wafers in order to increase efficiency and yields. All of the new reactors, however, will be capable of producing both HEMT and HBT wafers. The company also purchased 8,000 m^2 of land adjacent to its existing facility to allow for future expansion (GaAsNet, July 11, 2000, Picogiga purchases more production equipment for 6 inch wafers, accessed July 17, 2000, at URL http://www.gaasnet.com/news/picogiga2_0700.html; GaAsNet, October 20, 2000, VG Semicon receives Picogiga orders for two V150 production MBE systems, accessed October 31, 2000, at URL http://www.gaasnet.com/ news/vg_20102000.html; GaAsNet, November 5, 2000, Picogiga purchases three Applied Epi production MBE systems, accessed November 8, 2000, at URL http://www.gaasnet.com/news/appliedepi_05112000.html). Picogiga exported most of its production, with about 70% sold in the United States.

Germany.—In March, GEO Gallium S.A., a subsidiary of GEO Specialty Chemicals Inc., announced that it would increase gallium extraction capacity at its Stade plant by more than 50% by the summer of 2000. The company also said that, since it acquired the gallium business from Rhodia Inc. in 1999, it had increased the capacity at its Salindres, France, gallium refinery by more than 30% (Compound Semiconductor, March 1, 2000, GEO Gallium S.A. to expand its gallium extraction plant in Stade, Germany, accessed November 2, 2000, at URL http://www.compoundsemiconductor.net/PressReleases/2000/PR030100005.htm). With the expansions, estimated annual capacity at the Stade plant was 30 t, and at Salindres, 26 t.

Japan.—Gallium supply in Japan in 2000 was estimated to be 158 t, a 39% increase from the 1999 level, and demand was estimated to be 140 t in 2000, a 21% increase from that in 1999. Of the supply, 14 t came from domestic production, 65.8 t from imports, and 93.7 t from recycled scrap. Japan's imports in 2000 mainly came from Kazakhstan (23%), the United States (23%), and France (21%). Smaller quantities were imported from China, Germany, Hungary, Russia, and Slovakia. Dowa Mining planned to increase its production of gallium to between 14 t and 15 t in 2001 from the 2000 level of 8 t. The company also was investing in technology to recycle low-grade scrap (Roskill's Letter from Japan, 2001).

Hitachi Cable Ltd. announced plans to expand its GaAs production facilities further. By June 2001, the company plans to increase its monthly capacities as follows: Liquid-encapsulated Czochralski (LEC) substrates to 45,000 4-inch wafers, about 2.3 times existing capacity; boat-grown and vertical-gradient-freeze (VGF) substrates to 95,000 wafers, about 1.5 times existing capacity; MOVPE wafers to 24,000 4-inch diameter wafers, about 3 times existing capacity; and liquid-phase-epitaxial wafers to 59,000 wafers, about 1.7 times existing capacity. Total investment for the increased capacity was estimated to be 12 billion yen (¥) ($98.4 million) in equipment and plant upgrades (Hitachi Cable Ltd., October 11, 2000, Investment in compound semi-conductor facilities is upwardly revised to 12 billion yen this fiscal year, accessed February 8, 2001, via URL http://www2.hitachi-cable.co.jp/apps/smcinfo.nsf/new).

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In December, Matsushita Electronics Corp. announced that it would invest ¥22 billion ($198 million) to build a new 6-inch GaAs plant at its Uozu plant in Toyama Prefecture. Construction was scheduled to begin in January 2001, and the facility would be ready for operation in June 2002. This will be the company's second compound semiconductor production facility, and when finished, it will have a capacity of 6,000 6-inch wafers per month, more than double its existing output. The company said the new capacity is intended to keep up with growing demand from mobile appliance manufacturers. This would be the first 6-inch GaAs facility in Japan (Compound Semiconductor, 2000).

Fujitsu Quantum Devices was spending approximately $48 million to increase capacity at its 4-inch GaAs facility in Yamanashi Prefecture to 5,200 from 4,000 wafers per month. The company also planned to outsource some of its production so it would have a combined capacity equivalent to 8,000 4-inch wafers per month by the end of fiscal year 2002. In August, New Japan Radio Corp. announced that it planned to increase production of GaAs MMICs for use in mobile communications terminals. The company operated a 4-inch GaAs facility in Kawagoe (Compound Semiconductor, 2000).

Sumitomo Electric Industries planned to expand its manufacturing capabilities for GaAs. The company had invested more than ¥5 billion ($48 million) in new capital equipment for its existing compound semiconductor facility near Osaka, which resulted in increased GaAs substrate production in October. Sumitomo Electric Industries' 4-inch GaAs wafer capacity increased by 30%, 6-inch wafer capacity increased fivefold, and epitaxial wafer production tripled. Additional capacity expansion was already underway for 2001. The next phase of capital investment will increase not only GaAs substrates and epitaxial wafers but indium phosphide (InP) substrates as well (Compound Semiconductor, August 26, 2000, Sumitomo Electric expands capacity, accessed April 11, 2001, via URL http://www.compoundsemiconductor.net).

Toyoda Gosei Co. announced that it had begun mass producing GaN-base violet LEDs, becoming the world's first company to do so. Initially, the Toyota Motor Corp. affiliate will combine the LED with an optical catalyst for use in car air purifiers. The auto air purifier will decompose organic substances in the air into water and carbonic acid by exposing a titanium oxide optical catalyst to light from a violet LED. The device was installed in Toyota's remodeled Mark II passenger car released in October. The LED was expected to eventually be used in home electronics and lighting equipment, with projected annual sales of ¥1 billion ($8.2 million) in 2 to 3 years. Toyoda Gosei has already mass-produced green, blue, and blue-green LEDs. The 380-nanometer (nm) wavelength of the violet LED is shorter than that of other LEDs. Researchers at the firm added special materials in forming layers of GaN to produce the violet light. Toyoda Gosei and Nichia Corp. were suing each other over alleged LED patent infringements. In July, the Tokyo District Court ordered Toyoda Gosei to suspend production and sales of blue LEDs, and the firm took the case to a higher court (Compound Semiconductor, November 9, 2000, Toyoda Gosei mass produces violet LEDs, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net).

Taiwan.—In December, WIN Semiconductors Corp. finished building the first 6-inch GaAs MMIC foundry in Taiwan. Initial production was expected to be 10,000 wafer starts per year. By 2004, when the foundry was expected to be running at capacity, production would be 100,000 wafer starts per year (WIN Semiconductors Corp., December 12, 2000, WIN Semiconductors' GaAs MMIC wafer fab is officially opened—Leading the industry into the era of 6" wafer foundry services, accessed April 10, 2001, at URL http://www.winfoundry.com/news-htm/News010108142614.htm).

Advanced Wireless Semiconductor Co. began construction of a 6-inch GaAs HBT processing line in June. The new line would complement the company's existing 4-inch line. Both lines would have the capability to process 600 wafers per week. Advanced Wireless also signed a multiyear agreement with U.S.-based Conexant in which Advanced Wireless would supply Conexant with an additional 30,000 wafer starts per year. Production began in the fourth quarter of 2000 (Tim Whitaker, Compound Semiconductor, 2000, Fab four address growing GaAs markets, accessed April 9, 2001, via URL http://www.compoundsemiconductor.net).

Two Taiwanese companies, United Epitaxy Co. (UEC) and Epistar Corp., placed orders for a total of 25 MOCVD systems. UEC ordered 20 systems, 10 each from AIXTRON and EMCORE. The AIXTRON systems will be used to produce aluminum indium gallium phosphide (AlInGaP) high-brightness LEDs and 4- and 6-inch HBT epiwafers and to manufacture nitride LEDs. EMCORE was scheduled to deliver 10 MOCVD systems to UEC by mid-2002. The new systems will be used to produce high-brightness LEDs and electronic materials. UEC already had six EMCORE systems, which were used for the production of AlInGaP LEDs. Epistar purchased five AIXTRON reactors as part of its new expansion scheme. The machines will be used for AlInGaP-based yellow, orange, and red high-brightness LEDs in addition to blue and green nitride wafer manufacturing (Compound Semiconductor, 2000, MOCVD spending spree in Taiwan, accessed April 11, 2001, via URL http://www.compoundsemiconductor.net).

United Kingdom.—A new company to manufacture compound semiconductors was started in 2000 using technology and equipment transferred from the University of Glasgow and the University of Strathclyde. Compound Semiconductor Technologies Ltd. opened a facility in Glasgow that could produce GaAs, InP, gallium arsenide phosphide, and gallium aluminum arsenide wafers. In addition, the company planned to produce GaN using technology from the University of Strathclyde. At yearend, the company was producing about 100 2- and 3-inch wafers per month, but the equipment has the capability to process 4-inch wafers (Compound Semiconductor Technologies Ltd., September 2000, Glasgow wafer fab in gallium nitride bid, accessed February 8, 2001, at URL http://www.compoundsemi.co.uk/news-waferfab.htm).

IQE plc, a manufacturer of epitaxial wafers, acquired Wafer Technology Ltd., a substrate supplier, in November. The acquisition would allow IQE to have a captive substrate supplier for its epitaxial production. Wafer Technology produced 2- to 4-inch GaAs and InP substrates, as well as specialty III-V substrates, using the LEC and VGF methods (GaAsNet, November 24, 2000, IQE acquires Wafer Technology Limited, accessed November 27, 2000, at URL http://www.gaasnet.com/news/iqe_24112000.html).

Filtronic Compound Semiconductors Ltd., a unit of Filtronic plc, opened its new GaAs fabrication plant in August. The company acquired the facility in Newton Aycliffe, County Durham, England, from Fujitsu Ltd. in 1999. The 28,800-m^2 facility was purchased for about $20 million with financial assistance from the United Kingdom Government. Filtronic invested about $56 million in a retrofit before starting

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operations. Phase one of this plant was intended to provide a throughput of 30,000 6-inch wafers per year. This first stage utilizes about one-third of the available area, and Filtronic said that market demand would determine the future growth. Around 200 individual pieces of equipment had been purchased for the new plant, including 2 multiple-6-inch-wafer MBE systems. The company was also converting the former Litton Solid State Plant in Santa Clara, CA, to 6-inch operation, which would focus on process development and fast MMIC prototyping (Tim Whitaker, Compound Semiconductor, 2000, Fab four address growing GaAs markets, accessed April 9, 2001, via URL http://www.compoundsemiconductor.net).

Current Research and Technology

LumiLeds Lighting announced a breakthrough in its high-flux LEDs, with improvements in optical output power and efficiency. Aluminum indium gallium nitride (AlInGaN) technology is the standard technology for LEDs in the blue and green areas of the color spectrum. LumiLeds also has developed a unique power package that allows higher power LEDs to be housed and operated. Typical output of the new devices are blue LEDs, 100 milliwatts (mW) (5 to 8 lumens); green LEDs, 40 mW (10 to 20 lumens); and blue-green LEDs, 70 mW (15 to 25 lumens). By comparison, the industry standard 5-mm LED output was less than 10 mW in the blue spectrum. These devices also exhibited superior electrical and thermal characteristics. The new material was used in production LEDs beginning in November 2000 (LumiLeds Lighting, November 3, 2000, LumiLeds Lighting announces breakthrough in high-flux AlInGaN LEDs, accessed April 9, 2001, at URL http://www.lumileds.com/news/AlInGaN.html). LumiLeds Lighting is a joint venture between Agilent Technologies Inc. and Philips Lighting Co.

LumiLeds Lighting also announced a new product for channel-letter lighting that could replace neon as the primary lighting source in this application. The new "LED Rail" is a string of LEDs mounted on a patented rail system that allows for easy installation in standard channel letter housings. The LEDs are spaced such that they backlight the channel letter in a consistent manner. This was among the first solid-state lighting products on the market designed exclusively for channel letter lighting. The LED Rail contains no glass tubes. It is simply a string of wire with LED modules attached in fixed intervals. Glass can be a problem in signage because of breakage caused by harsh weather, transportation, and vandalism. The LED Rail operates at a lower voltage than neon, and it is easier to install than glass because there is no glass to bend. LumiLeds claimed that the LED Rail saves up to 80% of the energy used to light the same size neon-powered channel letters (Compound Semiconductor, March 31, 2000, LumiLeds Lighting introduces neon replacement solution for channel letter lighting using LEDs, accessed April 10, 2001, via URL http://www.compoundsemiconductor.net).

TriQuint received $3.1 million in funding from the U.S. Department of Commerce's National Institute of Standards and Technology to develop advanced, high-performance, low-cost GaAs-based HBT power amplifiers and incorporate them in compact multifunction chips for use in next-generation wireless communications and broadband cable systems. The 2.5-year project began in November, and the goal was to develop the HBT and build prototype cable television repeater amplifiers and circuits for advanced wireless base stations. TriQuint's partners in the project are ATMI and Linear Circuit Innovations Inc. (National Institute of Standards and Technology, October 2000, Advanced HBT power amplifier technology for broadband communications systems, accessed April 10, 2001, at URL http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=00-00-4019).

Applied Optoelectronics Inc. (AOI) entered into a licensing agreement with Lucent Technologies Inc. that gave AOI the right to manufacture and distribute quantum-cascade lasers for applications in industries other than telecommunications. The agreement marked the first time Lucent had licensed this technology. AOI was pursuing sensor applications in markets such as combustion diagnostics, environmental sensing, medical diagnostics, industrial process control, and law enforcement, and the new lasers were expected to be commercially available by September 2000. The quantum-cascade laser was invented and demonstrated in 1994 at Bell Laboratories. It operates in the midinfrared portion of the spectrum, in which it previously had been difficult for scientists to create high-efficiency lasers. This spectral region is particularly important from an applications standpoint because many chemicals—including pollutants, industrial chemicals, explosives, and medically important substances—can only be sensitively detected using midinfrared lasers. Efforts to create high-performance, low-cost laser-based sensors for these materials had been hampered by the high price or limited spectral or power performance of existing lasers. The crystal structure of the quantum-cascade laser contains up to 1,000 alternating layers of different types of crystalline material, some thinner than one-billionth of an inch (Lucent Technologies Inc., July 12, 2000, Applied Optoelectronics, Inc. signs licensing agreement with Lucent Technologies, accessed August 17, 2000, at URL http://www.lucent.com/press/0700/000712.bla.html).

Researchers at the U.S. Naval Research Laboratory and at Sarnoff Laboratories announced the development of the first room-temperature III-V laser diode that emits light at a wavelength greater than 3 micrometers (μm). The diodes consist of 10 W-shaped quantum wells grown on a gallium antimonide substrate. The W structure consists of a central gallium indium antimonide hole sandwiched between two indium arsenide electron wells, which are in turn bracketed by two high aluminum gallium arsenide antimonide barriers. This structure allows excellent electron confinement, allowing a low threshold current, which enable continuous wave operation at relatively high temperatures (195 K). The research team's next goal was to have the device operate at temperatures above 230 K to avoid the need for cryogenic cooling. Potential applications for the devices include portable pollution monitors, medical diagnostics, and chemical weapons site detectors (Gaughan, 2000).

A research team at the Tokyo Institute of Technology created a hybrid iron and semiconductor material that changes magnetic properties when excited by light. The device consists of 20 alternating layers of ferrite and GaAs on a GaAs substrate. The researchers excited the device with light perpendicular to its surface and observed positive magnetoresistance. When the light was turned off, the magnetization returned to its original value, which indicates that the magnetization is reversible and not caused by a change in the structure of the device. If this is fully commercialized, it may lead to development of faster optical storage media and may also produce a new light-sensitive toner for photocopiers (Whipple, 2000).

In October, Isonics Corp., Golden, CO, and Epichem Inc.,

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Allentown, PA, announced that they would establish a 2-year, jointly funded program to produced isotopically pure gallium for the semiconductor and optoelectronic business. The improved thermal conductivity provided by isotopically pure gallium can increase the performance and reliability some GaAs-base devices. Because the thermal conductivity of GaAs is about one-third that of silicon, improved thermal properties are likely to have substantial positive impact on the GaAs device performance (Isonics Corp., October 26, 2000, Isonics and Epichem start development of isotopically pure gallium, accessed November 2, 2000, at URL http://www.isonics.com/pr63.htm).

GaN continued to generate significant research interest at the academic level as well as on a commercial level. More than 100 companies and 200 universities worldwide were engaged in GaN material processing and device development. Europe with 37% and North America with 33% were the geographic areas where most of the groups were doing research and development (R.V. Steele, Compound Semiconductor, 2000, Update on GaN technology and markets, accessed April 9, 2001, via URL http://www.compoundsemiconductor.net). Much of the work centered on improving growth techniques and improving properties so that LEDs and laser diodes based on GaN technology could be commercialized.

AXT announced two new LED products, high-brightness cyan and green, which complimented the company's current offering of red, amber, yellow, and blue LEDs. The new 505-nm AlInGaN-based high-brightness cyan LED has a minimum power output of 1.2 mW at 20 milliamperes. High-brightness cyan LEDs were primarily used in traffic signals. Industry analysts estimated that the LED traffic signal market would reach approximately $100 million for 2000, and would grow at a rate of approximately 50% per year over the next few years. The new 525-nm AlInGaN-based high-brightness green LED has a minimum power output of 0.75 mW at 20 milliamperes. Because green is a primary color for light, by mixing red, green, and blue lights, many colors can be produced, including white light. With the high efficiency of this new product, many outdoor applications also would become feasible. High-brightness green LEDs were used in very large outdoor full-color displays, indoor displays, special-purpose illumination, cellular phone back lighting, traffic signals, as well as many consumer applications (Compound Semiconductor, April 28, 2000, American Xtal Technology announces new cyan and green LED products, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net). The company received a multimillion dollar contract for the new LEDs in September.

Cree Inc., Durham, NC, reported it demonstrated the first MMIC made from GaN grown on a semi-insulating silicon carbide substrate. The initial device achieved 20 watts of pulsed radio frequency (RF) output power at 9 gigahertz (GHz), which exceeded the highest output power of GaAs MMICs available for this frequency range. The company also demonstrated a record-setting 10 GHz radio frequency power performance from a GaN HEMT. The GaN HEMT transistor was incorporated into a hybrid amplifier that achieved 40 watts of pulsed radio frequency output power at 10 GHz. This was more than 2.5 times higher than had been publicly reported for a single semiconductor device at this frequency. Cree's work on GaN hybrid and MMIC amplifiers was funded in part by the Air Force Research Laboratories and the Office of Naval Research, respectively. The GaN discrete devices and MMICs that were under development were being targeted for high frequency (5 to 35 GHz) commercial broadband communications, as well as military radar and communications applications (GaAsNet, August 19, 2000, Cree achieves record power performance at 10 GHz, accessed August 29, 2000, at URL http://www.gaasnet.com/news/cree_19082000.html).

Cree Lighting Co., a subsidiary of Cree, reported that it demonstrated a near-ultraviolet-violet indium gallium nitride LED with 28% quantum efficiency. This was the highest known external quantum efficiency publicly reported for an LED in the ultraviolet-to-blue portion of the wavelength spectrum. The LED emits at 400 nm and has a power output of 17 mW. LEDs in this portion of the light spectrum are important for making white solid-state light bulbs using phosphors to convert the wavelength of the light emitter to the visible spectrum, then mix colors to make a white bulb. High quantum efficiency is critical to making energy-efficient, solid-state light bulbs. The new emitter demonstrated an overall efficiency of 22% (Compound Semiconductor, July 28, 2000, Cree demonstrates 28% quantum efficient InGaN LED, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net). Cree acquired Nitres Inc. in May 2000, renamed the company Cree Lighting, and began operating it as a wholly owned subsidiary. Nitres focuses on developing and commercializing nitride-based semiconductor materials and device technology; some research was funded though government and military contracts.

Cree and North Carolina State University filed a patent infringement lawsuit against Japan's Nichia Corp. and Nichia America Corp. in the U.S. District Court for the Eastern District of North Carolina. The lawsuit sought enforcement of a patent relating to GaN-based semiconductor devices manufactured using lateral epitaxial overgrowth (LEO) technology. The patent, U.S. patent No. 6,051,849, entitled "Gallium nitride semiconductor structures including a lateral gallium layer that extends from an underlying gallium nitride layer," was issued to North Carolina State University in April 2000 and was licensed to Cree under a June 1999 agreement from which Cree obtained rights to a number of LEO and related techniques. In its complaint, Cree alleges that Nichia was infringing the patent by importing, selling, and offering for sale in the United States certain GaN-based laser diodes covered by one or more claims of the patent. The lawsuit sought damages and an injunction against the infringement (Weiss, 2000).

Kyma Technologies Inc., a Research Triangle Park, NC, developer and supplier of nitride substrates, developed a 2-inch diameter, 50-μm thick epitaxial GaN layer, on a sapphire wafer, which was to be used as the core technology for a variety of applications within the optoelectronic, communications, and semiconductor industries. With existing technology, the typical epitaxial layer is 1 to 2 μm for sapphire-based GaN wafers. Kyma planned to ship samples to device developers by the end of 2000, with production quantities available in the first quarter of 2001 (Compound Semiconductor, November 2, 2000, 2-inch gallium nitride epitaxial substrate completed by Kyma Technologies, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net).

ATMI developed and patented processes that allow the manufacture of high-purity GaN wafers 50 mm and larger in diameter; large area GaN wafers were not commercially available because of the difficulty of producing bulk GaN crystals. Based on their success with the patented technique, ATMI committed significant additional funding for continued

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development and pilot manufacturing capacity. In addition, ATMI was awarded contracts totaling nearly $4 million from the Office of Naval Research and the Ballistic Missile Defense Organization for further development of GaN wafers for electronic and optoelectronic devices (Compound Semiconductor, October 17, 2000, A T M I announces optical materials initiative; gallium nitride wafer and epi expansion to support blue laser development, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net).

Nitronex Corp., a Raleigh, NC, semiconductor startup, announced that it received $500,000 in venture capital from Centennial Venture Partners, a $10 million venture fund started by North Carolina State University to help launch start-up companies affiliated with the university. Nitronex, founded in 1998, was set to begin scaling its proprietary technology for growing GaN on silicon. The company's PENDEO™ process, developed with researchers at North Carolina State, allows it to combine GaN with silicon to take advantage of the properties of both materials (Compound Semiconductor, February 7, 2000, Nitronex lands additional venture capital, accessed April 17, 2001, via URL http://www.compoundsemiconductor.net).

In July, Spectrolab Inc., Sylmar, CA, a unit of Boeing Co., claimed to have set a new world record by manufacturing satellite solar cells able to convert 29% of the sun's rays into spacecraft power. This surpassed the company's previous record of 27%, announced in April, for a space solar cell, and came only 7 months after achieving a 32.3% efficiency in terrestrial solar cells. Spectrolab planned to start production of this triple-junction GaAs-base solar cell in the third quarter of 2000. The average maximum power efficiency was expected to be 27.4%, with an end-of-satellite-life efficiency of 24.1% after 15 years in geosynchronous orbit (Spectrolab Inc., July 12, 2000, Spectrolab sets new world record with space solar cell efficiency of 29 percent, accessed November 28, 2000, via URL http://www.spectrolab.com).

Spectrolab announced that it would supply its solar cells to Dornier Satellitensysteme GmbH (DSS) of Germany under a technical assistance agreement between the two companies for qualification testing in the DSS space solar array systems. This was the first European agreement for Spectrolab since it received U.S. Government approval to provide solar components to major European spacecraft manufacturers. DSS was expected to purchase several hundred thousand multijunction solar cells through 2002. Once they are qualified, Spectrolab's multijunction GaAs solar cells are expected to improve the DSS solar array power performance by 40% compared to earlier designs using silicon cells. These multijunction space solar cells have an average efficiency of 24.5% and were qualified by the major U.S. satellite manufacturers. Spectrolab had been working under a jointly funded development contract with the U.S. Air Force to deliver 35%-efficient space solar cells by 2002 (Spectrolab Inc., May 20, 2000, Spectrolab to supply solar cells to German satellite builder Dornier, accessed April 19, 2001, via URL http://www.spectrolab.com).

In June, EMCORE announced that the company's new triple-junction GaAs-base solar cells with 26% efficiency were in production and were being shipped to customers for space qualifications. During qualification testing, these cells demonstrated a power loss of only 8% under a typical 15-year geostationary orbit characteristic of communication satellites. These new solar cells were expected to significantly improve satellite communications economics by increasing payload capabilities (EMCORE Corp., June 27, 2000, EMCORE announces production of 26% efficiency triple-junction solar cells, accessed April 19, 2001, at URL http://www.emcore.com/html_documents/News_clips/2000/Triple_Junction.htm). The company also produced a dual-junction solar cell for satellite applications that has an efficiency ranking of 25.3%. The dual-junction InGaP/GaAs compound semiconductor solar cell product is grown on a germanium substrate (EMCORE Corp., February 2, 2000, EMCORE announces shipment of world's highest efficiency dual junction solar cells, accessed April 19, 2001, at URL http://www.emcore.com/html_documents/News_clips/2000/shipment_highest_efficency_solar_cell.htm).

Scientists at Sandia National Laboratories were investigating indium gallium arsenide nitride (InGaAsN) as a potential photovoltaic power source for space communications satellites. This material, which may be used as a solar cell, has a potential 40% efficiency rate when put into a multilayer cell, which is nearly twice the efficiency rate of a standard silicon solar cell. An InGaAsN solar cell that could provide power to a satellite would ultimately have four layers. The top layer would consist of indium gallium phosphide, the second of GaAs, the third of 2% nitrogen with indium in GaAs, and the fourth of germanium. Each layer absorbs light at different wavelengths of the solar spectrum. The first layer absorbs yellow and green light, the second absorbs between green and deep red, the third absorbs between deep red and infrared, and the fourth absorbs infrared and far infrared. The absorbed light creates electron hole pairs. Electrons are drawn to one terminal and the holes to the other, thus producing electrical current (U.S. Department of Energy, Sandia National Laboratories, March 8, 2000, New semiconductor alloy's 'crazy physics' makes it a possible photovoltaic power source for satellites, accessed June 16, 2000, at URL http://www.sandia.gov/media/NewsRel/NR2000/InGaAsN.htm).

Also at Sandia, researchers constructed a two-dimensional GaAs artificial crystal that conducts light. The crystal's appearance resembles that of cheesecloth; this structure could be considered essentially a wire for light, because the specific size and periodic placement of the holes create a structure that blocks most light waves while transmitting those in a selected band of wavelengths. Because of the very small light loss, the technique offered the potential of ultimately replacing electronic chips with faster, cooler photonic chips. The technique could be used to combine light with electrons in a single chip. It also could be used to relay and change the direction of optical signals coming through telecommunications lines. The GaAs structure potentially may significantly reduce the energy needed to start and operate a laser. Although researchers say that the crystal structure was easy to fabricate, it was difficult to build and test without the structure cracking (U.S. Department of Energy, Sandia National Laboratories, October 27, 2000, Cheesecloth-like device bends light with little loss, accessed April 24, 2001, at URL http://www.sandia.gov/media/NewsRel/NR2000/cheese.htm).

Working with colleagues at Brown University, research personnel at Sandia demonstrated a prototype of the first VCSEL that emits ultraviolet light. While project work had been ongoing for 3 years, a key advance took place when indium was added to the VCSEL materials mix in August 1999. VCSELs are made of nanoscopically thin layers of semiconductor materials that emit photons when electricity is passed through them. While GaN and aluminum nitride both emit in the ultraviolet range, the efficiency with which those

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materials make use of input power is not high, only about 1%. Adding indium brought the VCSEL efficiency to a starting point of 20%, although it pushed the wavelength emitted longer into the near-ultraviolet range, about 380 nm. The successful synthesis of highly reflective bottom mirrors from aluminum gallium nitride was another important factor in making the prototype. Among their benefits, ultraviolet VCSELs coated with phosphors have the capability to generate the white light that could be used in indoor lighting. Easily portable ultraviolet laser light also causes weapons-grade fissionable materials and *E. coli* bacteria to fluoresce in the visible spectrum, aiding in the detection of attempted materials thefts and preventing the spread of bacterial epidemics (U.S. Department of Energy, Sandia National Laboratories, October 17, 2000, Sandia VCSEL generates ultraviolet light, accessed April 24, 2001, at URL http://www.sandia.gov/media/NewsRel/NR2000/UVVCSEL.htm).

Outlook

According to information compiled by CIBC World Markets, a unit of the Canadian Imperial Bank of Commerce, the GaAs industry is expected to decline in 2001, the first significant downturn in this industry. The company predicts that unless the cellular phone business shows a significant turnaround, GaAs sales could decline by as much as 15% in 2001. CIBC projected that the total number of mobile phone handsets sales in 2001 would be about 475 million units, an increase from the 410 million units sold in 2000. But there is significant inventory in this industry, which would be sufficient to supply the increase in demand, so the net gain would be essentially zero (Compound Semiconductor, 2001). According to CIBC, the leading world suppliers, based on a percentage of the value in 1999, are Fujitsu (11.1%), Mitsubishi Electric Corp. (10.1%), RF Micro Devices (9.6%), Motorola (7.4%), and Conexant (6.7%).

With a growth rate exceeding 58% per year for the past 5 years, Strategies Unlimited projected that the worldwide market for high-brightness LEDs reached $1.2 billion in 2000 and accounted for 42% of the total LED market. The company projected continued robust growth for the next 5 years, with the market expected to exceed $3.4 billion in 2005 (Compound SemiOnline, April 6, 2001, High brightness LED market forecast to reach $3.4 billion by 2005, accessed May 22, 2001, at URL http://compoundsemi.com/documents/view/generic.php3?id=389#top). The company expects that such markets as backlighting for mobile phones may experience a slowdown, but demand for very-high-brightness products for outside video displays, signage, and traffic signals will remain strong.

Until recently, the only significant market for GaN devices has been for high-brightness blue, green, and white LEDs. Since the announcement of high-brightness GaN-based blue LEDs in late 1993, the market grew from virtually nothing to $420 million by 1999. Since 1995, the growth rate had been estimated to be 79% per year. GaN-based blue, green, and white LEDs are used in a variety of applications, including full-color outdoor signs, automotive interior lighting, traffic signals, backlights for cell phone displays, niche illumination applications, and general purpose indicator and display applications. GaN-based blue-violet laser diodes operating at 405 nm, developed by Nichia, were introduced to the market on a sample basis in early 1999. These devices are used in a variety of applications, including sensing, spectroscopy, laboratory research and next-generation optical storage system development. No commercial blue-laser-based optical storage systems had been introduced. The GaN device market, however, was projected to experience strong growth over the next decade. Blue laser diodes will begin to be used in high-density DVD drives in 2002 and will capture a large share of the optical storage market in subsequent years. The total GaN device market was projected to grow to more than $4.8 billion by 2009 representing a compound annual growth rate of 28% from 1999 (R.V. Steele, Compound Semiconductor, 2000, Update on GaN technology and markets, accessed April 9, 2001, via URL http://www.compoundsemiconductor.net).

Forecasts of large growth in demand for gallium-based devices are based on the assumption of no significant changes in the overall world economy. If there is a significant decline in the world economy, these growth scenarios are too optimistic. Any growth in the use of gallium-based devices, however, will require additional gallium production capacity to be constructed. At current rates of world consumption, there is not enough virgin gallium supply available, as is evidenced by the situation at yearend 2000. Some of the supply problems should be alleviated when GEO Gallium's 100-t/yr gallium extraction plant comes on-stream in Australia in 2002.

References Cited

Compound Semiconductor, 2000, GaAs building boom hits Japan: Compound Semiconductor, v. 6, no. 9, December 2000-January 2001, p. 25.

———2001, GaAs industry warned of uncertain future: Compound Semiconductor, v. 7, no. 3, April, p. 7-8.

Gaughan, Richard, 2000, Researchers develop mid-IR room-temperature laser: Photonics Spectra, v. 34, no. 2, February, p. 37-38.

Hausken, Tom, 2001, Components market reaches $18 billion: Compound Semiconductor, v. 7, no. 3, April, p. 37-39.

Mining Journal, 2000, Minor metals in August: Mining Journal, v. 335, no. 8600, September 15, p. 219.

———2001, Minor metals in December [2000]: Mining Journal, v. 336, no. 8615, January 5, p. 13.

Roskill's Letter from Japan, 2001, Gallium—Supply needs to rise by 40-60t to meet growth in demand: Roskill's Letter from Japan, no. 293, January, p. 2-4.

Weiss, S.A., 2000, Cree to US courts—Stop Nichia's blue laser sales: Photonics Spectra, v. 34, no. 12, December, p. 56.

Whipple, C.T., 2000, Light induces magnetism in material: Photonics Spectra, v. 34, no. 10, October, p. 28.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Gallium. Ch. in Mineral Commodity Summaries, annual.

Gallium, Germanium, and Indium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Compound Semiconductor.

Gallium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Gallium. Roskill Information Services Ltd., 2000.

Gallium and Gallium Arsenide—Supply, Technology, and Uses. U.S. Bureau of Mines Information Circular 9208, 1988.

Mining Journal.

Minor Metals in the CIS. Roskill Information Services Ltd., 1997.

Roskill's Letter from Japan.

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TABLE 1
SALIENT U.S. GALLIUM STATISTICS 1/

(Kilograms, unless otherwise specified)

	1996	1997	1998	1999	2000
Production	--	--	--	--	--
Imports for consumption	30,000	19,100	26,300	24,100	39,400
Consumption	21,900	23,600	26,900	29,800	39,900
Price per kilogram	$425	$595	$595	$640	$640

-- Zero.

1/ Data are rounded to no more than three significant digits.

TABLE 2
U.S. CONSUMPTION OF GALLIUM, BY END USE 1/ 2/

(Kilograms)

End use	1999	2000
Optoelectronic devices:		
Laser diodes and light-emitting diodes	12,500	12,600
Photodetectors and solar cells	712	267
Integrated circuits:		
Analog	15,300	25,200
Digital	686	1,130
Research and development	572	701
Other	60	95
Total	29,800	39,900

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes gallium metal and gallium compounds.

TABLE 3
STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, BY GRADE 1/ 2/

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1999:				
99.99% to 99.999%	890	399	632	657
99.9999%	108	13,600	13,200	485
99.99999% to 99.999999%	1,000	16,000	16,000	1,020 r/
Total	2,000	30,000 r/	29,800	2,160 r/
2000:				
99.99% to 99.999%	657	--	179	478
99.9999%	485	13,400	13,500	341
99.99999% to 99.999999%	1,020	25,400	26,300	136
Total	2,160	38,700	39,900	955

r/ Revised. -- Zero.

1/ Consumers only.

2/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 4
YEAREND GALLIUM PRICES

(Dollars per kilogram)

	1999	2000
Gallium metal, 99.99999%-pure, 100-kilogram lots	640	640
Gallium metal, 99.9999%-pure, 100-kilogram lots	595	595
Gallium metal, 99.9999%-pure, imported	380-425	380-425
Gallium oxide, 99.99%-pure, imported	275-350	275-350

Source: American Metal Market.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT, WASTE AND SCRAP), BY COUNTRY 1

	1999		2000	
Country	Quantity (kilograms)	Value	Quantity (kilograms)	Value
China	99	$37,100	685	$368,000
France	7,750	3,200,000	24,800	9,510,000
Germany	2,490	1,240,000	731	207,000
Hungary	1,760	491,000	1,470	601,000
Japan	354	286,000	898	746,000
Kazakhstan	7,330	3,350,000	4,840	2,490,000
Korea, Republic of	--	--	1,200	1,430,000
Russia	2,470	1,060,000	2,100	1,590,000
United Kingdom	1,240	532,000	1,940	1,040,000
Other	575	175,000	672	450,000
Total	24,100	10,400,000	39,400	18,400,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
ESTIMATED WORLD ANNUAL PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2000 1/

(Metric tons)

Country	Capacity
Australia 2/	50
China	20
Germany	30
Hungary	8
Japan	20
Kazakhstan	20
Slovakia	8
Russia	19
Ukraine	5
United States 2/	3
Total	183

1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Standby capacity as of December 31, 2000

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GARNET, INDUSTRIAL

By Donald W. Olson

Domestic survey data and tables were prepared by Christine K. Pisut, statistical assistant.

The angular fractures and high hardness of garnet and its ability to be recycled make it desirable for a variety of abrasive purposes. The complex mineralogy of garnet determines its utility for a variety of uses ranging from a filtration medium to a waterjet abrasive.

Garnet is the general name for a group of complex silicate minerals with similar crystalline structures and diverse chemical compositions. The general chemical formula is $A_3B_2(SiO_4)_3$, where "A" can be calcium, magnesium, ferrous iron, or manganese, and "B" can be aluminum, chromium, ferric iron, or rarely, titanium. Garnet occurs worldwide in many rock types, principally gneisses and schists; other sources include contact metamorphic rocks, crystalline limestones, pegmatites, and serpentinites. Alluvial garnet is associated with heavy mineral sand and gravel deposits in many parts of the world. Occurrences of garnet are large and numerous; however, relatively few commercially viable garnet deposits have been discovered.

Mine output of industrial garnet in the United States decreased slightly in 2000 compared with that of 1999, while the value of U.S. industrial garnet production increased by about 14% over that of 1999. The one mining operation in the United States that had closed down in 1999 was purchased during 2000 and began producing from stocks.

Production

The U.S. industrial garnet industry is dominated by a few major producers. The industrial garnet market is influenced by the size and grade of reserves, the type and quality of garnet mined, the proximity of deposits to infrastructure and consumers, and the milling costs. Pricing within the U.S. garnet industry is very competitive, and suppliers must provide a high level of customer service. Most industrial-grade garnet mined in the United States is almandine (iron-aluminum silicate) and pyrope (magnesium-aluminum silicate), although andradite (calcium-iron silicate) is also a domestic source for industrial uses.

The United States produced approximately 20% of the industrial garnet mined worldwide in 2000. According to a survey conducted by the U.S. Geological Survey (USGS), five U.S. companies in Idaho, Montana, and New York accounted for all domestic output. Production decreased slightly to 60,200 metric tons (t), whereas the value of annual production grew by 14% to about $7.1 million in 2000 (table 1). The producers were Barton Mines Co. LLC in Warren County, NY; Emerald Creek Garnet Co. in Benewah County, ID; Montana-Oregon Investment Group LLC in Madison County, MT; NYCO Minerals, Inc. in Essex County, NY; Patterson Materials Corp.

Industrial Garnet in the 20th Century

Garnet is mined as a gemstone and an industrial material, but it is valued primarily for its many industrial applications. The United States developed substantial garnet abrasive technology and applications earlier than other countries mainly because of the large deposits of high-quality abrasive garnet in New York. The deposits were first commercially developed in 1878. In 1900, annual production of industrial garnet in the United States was about 2,890 metric tons valued at about $123,000. Production was primarily in Maine, New York, North Carolina, Pennsylvania, and Virginia. There are no data to indicate that the United States had any foreign trade in industrial garnet in 1900. The price at the mine varied from $25 to $60 per ton. The main use for industrial garnet was in the sandpaper industry. At the end of World War II in 1945, U.S. industrial garnet production and consumption began a steady rise that roughly paralleled the rise in new home starts. The most significant jump in U.S. garnet production and consumption began in 1987, when health risks were first associated with the inhalation of airborne crystalline silica dust, and garnet began to replace crystalline silica as a sand blasting medium.

In 2000, domestic crude garnet production was estimated to be 60,200 tons, with an estimated value of more than $7 million; the value of refined garnet material was estimated to be $14 million. Garnet for industrial use was mined in 2000 by five firms: three in New York, one in Idaho, and one in Montana. In 2000, U.S. imports and exports of industrial garnet were about 23,000 tons and 10,000 tons, respectively. Imports were mostly from Australia, India, and China. Domestic consumption of garnet was estimated to be about 25,000 tons. Values for crude concentrates ranged from about $53 to $254 per ton, and values for refined garnet ranged from $61 to $441 per ton. By the end of the 20th century, major end uses for industrial garnet in the United States were abrasive sand blasting media, filtration media, precision abrasive powders, waterjet abrasives, and other miscellaneous abrasive uses, ranging from nonskid surfaces to finishing of plastic and wood products. In 2000, industrial garnet was still gradually displacing crystalline silica sand in the blast cleaning market, due to the health risks associated with the use of crystalline silica and due to garnet's ability to be recycled for reuse several times.

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in Dutchess County, NY; and Sweetwater Garnet Inc. in Madison County, MT. All but one of the producers reported their output and sales to the USGS, and production and values for the nonreporting company were estimated. In addition to the producers cited above, International Garnet Abrasive Inc. in Clinton County, NY, processed and sold all of the garnet mined by NYCO Minerals in 2000.

Sweetwater Garnet, which had shut down in 1999, was sold in July 2000 to Stansbury Holdings Corporation. In the fall of 2000, Stansbury resumed operations at Sweetwater after upgrading the mill and was producing from stocks.

Consumption

The United States was the world's largest consumer of industrial garnet, accounting for 20% to 25% of global consumption (Harris, 2000). In 2000, the U.S. apparent consumption of industrial garnet was estimated to be 25,400 t, which was a 45% decrease from the 1999 apparent consumption. This apparent consumption decrease was due to a 75% increase in U.S. producer stocks. Most of these stocks were concentrated in two of the U.S. industry's five producers.

Major end uses in the United States and their estimated market share were abrasive blasting media, 45%; water filtration, 15%; abrasive powders, 10%; waterjet cutting, 10%; and other miscellaneous abrasive uses, 20%. Domestic consumption approximated world demand patterns, except that filtration uses abroad accounted for a greater market share. U.S. industries that consumed industrial garnet included aircraft manufacturers, ceramics and glass producers, electronic component manufacturers, motor vehicle manufacturers, the petroleum industry, shipbuilders, water filtration plants, and wood-furniture-finishing operations.

The majority of industrial garnet is used as a loose-grain abrasive because of its hardness, which ranges from 6 to 7.5 on the Mohs scale. Lower-quality industrial garnet is used as a filtration medium in water-purification systems because of its relative inertness and chemical degradation resistance. High-quality, high-value garnet grain has been used principally for such applications as optical lens grinding and plate-glass grinding for more than a century; industrial diamond and fused aluminum oxide are competitors in this application. In recent years, industrial garnet powders have been used for high-quality, scratch-free lapping of semiconductor materials and other metals. Other applications include the manufacture of coated abrasives; hydrocutting; and the finishing of wood, leather, hard rubber, felt, and plastics. Garnet has been slowly replacing silica sand in the blast cleaning market. This market displacement is happening because of the health risks associated with the inhalation of airborne crystalline silica dust having curtailed its use, but silica sand and slag are still the most widely used media in blasting (Harris, 2000).

The U.S. petroleum industry is one of the largest garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Huge crude oil price increases during 2000 allowed for the performance of previously deferred equipment maintenance activities and increased the petroleum industry's use of industrial garnet (Frank Alsobrook, President, Alsobrook and Company, Inc., oral commun., November 8, 2000).

The shipbuilding and aluminum aircraft industries use garnet for blast cleaning and for finishing metal surfaces. Similar uses include the cleaning and conditioning of aluminum and other soft metals, as well as metal cleaning by structural steel fabrication shops. Mixed-media water filtration, using a mixture of sand, anthracite, and garnet, has displaced older filtration methods because it is more reliable and provides better water quality; ilmenite, magnetite, and plastics compete as filtration media. Garnet entrained in high-pressure streams of water is also used to cut many different materials. The garnet powders generally are used for glass/ceramic polishes, antislip paints, and antiskid surfaces.

In the coated-abrasive market, garnet has an intermediate place between low-cost quartz sand or staurolite and such more costly manufactured abrasives as silicon carbide and fused alumina; garnet is more efficient than quartz sand in most coated-abrasive applications. Because of its friable nature and lower hardness, garnet cannot compete with manufactured abrasives in metalworking applications that require substantial metal removal.

Prices

The wide price range of industrial garnet was based on the type, source, quantity purchased, quality, and application. In 2000, average values for crude concentrates ranged from about $53 to $254 per ton, and average values for refined garnet sold during the year ranged from $61 to $265 per ton. However, spot prices reached as high as $441 per ton. Quantities sold by U.S. producers increased by approximately 17%, and the value of sales increased by about 21% during 2000.

Foreign Trade

The U.S. Government no longer compiles trade data that can be used to identify garnet exports and imports specifically. Based on reports from some producers and other industry sources, however, exports and imports of industrial garnet were estimated to be about 10,000 t and 23,000 t, respectively, in 2000. Some of the imports were not consumed during the year. Most U.S. garnet exports went to Asian and European markets.

About 40% to 45% of the U.S. garnet imports were from Australia, 35% to 40% from India, and 15% from China (Frank Alsobrook, President, Alsobrook and Company, Inc., oral commun., November 8, 2000). Australia historically has accounted for most of the industrial garnet imported by the United States. Imports of garnet from India are increasing, and both China and India have the potential to gain a significant share of the U.S. market (Frank Alsobrook, President, Alsobrook and Company, Inc., oral commun., November 8, 2000).

World Review

Total world industrial garnet production was estimated to be 335,000 t (Roskill Information Services Ltd., 2000). Australia, China, India, and the United States were the most significant producers in 2000. The United States produced approximately 20% of the industrial garnet mined worldwide. Australia and India exceeded U.S. production. Russia and Turkey have been

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mining garnet in recent years, primarily for domestic markets. Additional garnet resources with small mining operations are located in Canada, Chile, the Czech Republic, Pakistan, South Africa, Spain, Thailand, and Ukraine. Output in most of these countries is for domestic use (Frank Alsobrook, President, Alsobrook and Company, Inc., oral commun., November 8, 2000).

Australian exports of garnet are expected to continue to increase. China and India also have increased garnet output and are likely to become more significant garnet sources for other countries.

Outlook

Industrial garnet sold by U.S. producers increased by about 17% during 2000, and some forecasts indicate that domestic markets for industrial garnet may continue to grow in the next several years. Worldwide industrial garnet demand is expected to grow over the next 5 years at a rate of 3% to 5% per year. Markets for waterjet cutting and blasting media are expected to exhibit the highest growth (Roskill Information Services Ltd., 2000). With recent worldwide increases in petroleum prices, there has been an increase in petroleum exploration and in the use of garnet blasting media for cleaning drill pipe by the oil and gas industry. Increased defense spending in the United States could lead to increased garnet demand, since the aircraft manufacturing and shipbuilding industries use significant amounts for blast cleaning and finishing of metal surfaces. Substitution for silica sand by garnet in abrasive blasting markets will also continue but at a pace slower than expected by the most optimistic forecasts because silica sand has a price advantage and is more accessible to consumers. Growing world demand encourages new companies to enter the garnet industry, but the current major producers will continue to be the dominant suppliers in the first decade of the 21st century.

Increased producer stocks are being reported in the United States, and significant stocks of industrial garnet are held in Australia and India. These excess production stocks coupled with possible future expansions will not only meet anticipated market needs, but may also result in widespread garnet price decreases until supply and demand come into balance.

References Cited

Harris, Paul, 2000, At the cutting edge—Abrasives & their markets: Industrial Minerals, no. 388, January, p. 19-27.

Roskill Information Services Ltd., 2000, The economics of garnet (3d ed.): London, Roskill Information Services Ltd., 88 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Abrasives. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Garnet, Industrial. Ch. in Mineral Commodity Summaries, annual.

Other

Industrial Minerals (monthly).

Industrial Minerals Prices and Data (annual).

North American Minerals News (monthly).

TABLE 1
SALIENT U.S. INDUSTRIAL GARNET STATISTICS 1/

	Crude production		Sold or used 2/	
Year	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1996	60,900	$5,630	46,200	$11,200
1997	64,900	6,050	53,600	12,500
1998	74,000	7,070	51,900	12,600
1999	60,700	6,170	43,900	11,600
2000	60,200	7,060	51,300	14,000

1/ Data are rounded to no more than three significant digits.
2/ May exclude some unreported exports.

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GEMSTONES

By Donald W. Olson

Domestic survey data and tables were prepared by Christine K. Pisut, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Humans have been intrigued by gems since prehistoric times. They have been valued as treasured objects throughout history by all societies in all parts of the world. The first stones known to have been used for making jewelry include amber, amethyst, coral, diamond, emerald, garnet, jade, jasper, lapis lazuli, pearl, rock crystal, ruby, serpentine, and turquoise. These stones served as status symbols for the wealthy. Today, gems are not worn to demonstrate wealth as much as they are for pleasure or in appreciation of their beauty (Schumann, 1998, p. 8). In this report, the terms "gem" and "gemstone" mean any mineral or organic material (such as amber, pearl, and petrified wood) used for personal adornment, display, or object of art because it possesses beauty, rarity, and durability. Of the 2,700 mineral species, only about 100 possess all these attributes. Silicates compose the largest group of gemstones; oxides and quartz compose the second largest (table 1). A further subcategory of gemstones is "colored gemstone," which in this report designates all nondiamond gemstones, including amber, coral, and shell. In addition, synthetic gemstones, cultured pearls, and gemstone simulants are discussed but are treated separately from natural gemstones (table 2). Current information on industrial-grade diamond can be found in the U.S. Geological Survey (USGS) minerals yearbook chapter on industrial diamond.

Production

Commercial mining of gemstones has never been extensive in the United States. More than 60 varieties of gemstones have been produced commercially from domestic mines, but most of the deposits have been relatively small compared with other mining operations. In many instances, contemporary gemstone mining in the United States is conducted by hobbyists, collectors, and gem clubs rather than business organizations.

The commercial gemstone industry in the United States consists of several distinct sectors: (1) individuals and companies that mine gemstones or harvest shell and pearl, (2) firms that manufacture synthetic gemstones, and (3) individuals and companies that cut natural and synthetic gemstones. The domestic gemstone industry is focused on the production of colored gemstones and on the cutting of large diamonds. Industry employment is estimated to range from 1,000 to 1,500 workers (U.S. International Trade Commission, 1997, p. 1).

Most natural gemstone producers in the United States are small businesses that are widely dispersed and operate independently. The small producers probably have an average of less than three employees, including those who only work part time. The number of gemstone mines operating from year to year fluctuates, because the inherent uncertainty associated with the discovery and marketing of gem-quality minerals makes it difficult to obtain financing for developing and sustaining economically viable deposits (U.S. International Trade Commission, 1997, p. 23).

The total value of natural gemstones produced in the United States during 2000 was estimated to be at least $17.2 million (table 3). The production value was 6.9% greater than the preceding year. The production growth was mostly because the 2000 shell harvest was 42% larger than in 1999 and foreign markets for U.S. shell material grew as the demand from Southeast Asia cultured pearl producers increased (Jewellery News Asia, 2000b).

The estimate of 2000 U.S. gemstone production was based on

Gemstones in the 20th Century

In 1900, U.S. production of gemstones was valued at about $233,000. The top five gemstone types, in descending order of production value, were turquoise, sapphire, rhodolite (garnet), aquamarine, and quartz crystal; these accounted for about 85% of total domestic production. Turquoise was produced primarily in Nevada and New Mexico. Sapphire production was in Montana, rhodolite and beryl production occurred in North Carolina, and quartz crystal production was in California and Montana. In 1900, the United States also imported diamond and other gemstones valued at about $13.6 million. Nearly $4 million worth of these imports were rough South African diamonds that were all cut in the United States. Opals from Australia that were cut in the United States were also a significant portion of these imports.

In 2000, domestic gemstone production was estimated to be $74.3 million, of which an estimated $57.1 million was synthetic gemstone and $17.2 million was natural gemstone. The top seven natural gemstone types, in descending order of production value, were shell, beryl, agate, turquoise, quartz, coral, and gem feldspars; these accounted for about 47% of the total natural gemstone production. Output of natural gemstones was primarily from Tennessee, Arizona, California, Nevada, and Utah, in decreasing order. Reported output of synthetic gemstones was from five firms in North Carolina, New York, Florida, California, and Arizona, in decreasing order of production. There was notable production of freshwater pearl in Tennessee, turquoise in Arizona, and beryl in North Carolina and Utah. In 2000, the United States also imported diamond and other gemstones valued at about $12.9 billion. Of these imports, 79% was from Israel, India, and Belgium, in descending order of gemstone import value. Diamond imports accounted for 93% of the total value of gemstone imports, and slightly more than 10.4% by weight of those diamonds was cut in the United States.

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a survey of more than 200 domestic gemstone producers conducted by the USGS. The survey provided a foundation for projecting the scope and level of domestic gemstone production during the year. However, the USGS survey did not represent all gemstone activity in the United States, which includes thousands of professional and amateur collectors. Consequently, the USGS supplemented its survey with estimates of domestic gemstone production from related published data, contacts with gemstone dealers and collectors, and information garnered at gem and mineral shows.

Natural gemstone materials indigenous to the United States are collected, produced, and/or marketed in every State. During 2000, all 50 States produced at least $1,000 worth of gemstone materials. Five States accounted for about than 75% of the total value, as reported by survey respondents. These States, in order of declining value of production, were Tennessee, Arizona, California, Nevada, and Utah. Some States were known for the production of a single gemstone material, Tennessee for freshwater pearls and Arkansas for quartz, for example. Other States produced a variety of gemstones, like Arizona, whose gemstone deposits included agate, amethyst, azurite, chrysocolla, fire agate, garnet, jade, malachite, obsidian, onyx, peridot, petrified wood, opal, smithsonite, and turquoise. A wide variety of gemstones also were found in California, Idaho, Montana, and North Carolina.

There were only two operations on significant known diamond-bearing areas in the United States during 2000. The first is the Kelsey Lake Diamond Mine, which straddles the Colorado-Wyoming State line. Kelsey Lake is now the only commercial producing diamond mine in the United States. It is operated by Great Western Diamond Co., a wholly-owned subsidiary of McKenzie Bay International Ltd., who purchased the property from Redaurum Ltd. in April 2000 (McKenzie Bay International Ltd., May 1, 2000, Kelsey Lake Diamond Mine released from bankruptcy proceedings Yes International to perform investor relations, accessed November 20, 2000, at URL http://www.mckenziebay.com/news/archive/000501.htm). Diamonds are present in three of the nine known kimberlite pipes on the Kelsey Lake property. The remaining six kimberlites have yet to be fully explored and tested for their diamond potential. Of diamonds recovered, 50% to 65% were clear gem quality, and almost a third were 1 carat or larger in size. The identified resources are at least 17 million tons (Mt) grading at an average of 4 carats per hundred tons (J. Taylor, April 11, 2000, McKenzie Bay International Ltd., accessed July 16, 2001, at URL http://www.mckensiebay.com/reports/jt000411.htm). Kelsey Lake was reopened and began production again in September 2000, after installing new equipment in the main processing and recovery plant. Maximum diamond recovery rates are expected in 2001 (McKenzie Bay International Ltd., September 6, 2000, Diamond production begins at Kelsey Lake Diamond Mine, accessed November 20, 2000, at URL http://www.mckenziebay.com/news/archive/000906.htm). The second operation was in Crater of Diamonds State Park near Murfreesboro in Pike County, AR, where a dig-for-fee operation for tourists and rockhounds is maintained by the State. Crater of Diamonds is the only diamond mine in the world that is open to the public. The diamonds occur in a lamproite breccia tuff associated with an extinct volcanic pipe and in the soil developed from the lamproite breccia tuff. Since the diamond-bearing pipe and the adjoining area became a State park in 1972, over 21,000 diamonds have been recovered. Recent exploration demonstrated that there are some 78.5 Mt of diamond-bearing rock in this diamond deposit (Howard, 1999, p. 62). An Arkansas law, enacted early in 1999, prohibits commercial diamond mining in the park (Diamond Registry Bulletin, 1999).

In addition to natural gemstones, synthetic gemstones and gemstone simulants are produced in the United States. Synthetic gemstones have the same optical, physical, and chemical properties as the natural materials that they appear to be. Simulants have an appearance similar to that of a natural gemstone material, but they have different optical, physical, and chemical properties. Synthetic gemstones produced in the United States include alexandrite, diamond, emerald, moissanite, ruby, sapphire, turquoise, and zirconia. Simulants of coral, lapis lazuli, malachite, and turquoise also are manufactured. In addition, certain colors of synthetic sapphire and spinel, used to represent other gemstones, are classified as simulants.

Synthetic gemstone production in the United States exceeded $57 million during 2000; simulant gemstone output was even greater and was estimated to be more than $100 million. Five firms in five States, representing virtually all the U.S. synthetic gemstone industry, reported production to the USGS. The States with reported synthetic gemstone production were Arizona, California, Florida, New York, and North Carolina. At least one U.S. company has developed technology to produce consistent quality and quantities of synthetic diamond and has reported production during 2000. The synthetic diamond stones weight ranged from 1.5 to 2 carats.

In 2000, a North Carolina firm entered its third year of marketing moissanite, a gem-quality synthetic silicon carbide that it produces. Moissanite is also an excellent diamond simulant, but it is being marketed for its own gem qualities.

Consumption

Although the United States accounts for less than 1% of total global gemstone production, it is the world's leading gemstone market. On the basis of indicators, such as trade data and income growth rates, U.S. gemstone markets—bolstered by strong demand among consumers with more personal wealth and more discretionary income—apparently accounted for at least 35% of world gemstone demand in 2000. The U.S. market for unset gem-quality diamonds during the year was estimated to have exceeded $9 billion, the largest in the world. Domestic markets for natural, unset nondiamond gemstones totaled about $770 million.

According to a poll conducted by a U.S. jewelry retailers association in the mid-1990s, about two-thirds of domestic consumers who were surveyed preferred diamond as their favorite gemstone (ICA Gazette, 1996). In 2000, the top-selling colored gemstones, in descending order, were blue sapphire, ruby, emerald, amethyst, tanzanite, tourmaline, garnet, fancy sapphire, pearl, and blue topaz (Prost, 2001). In addition to jewelry, gemstones are used for collections, exhibits, and decorative art objects.

Prices

Gemstone prices are governed by many factors and qualitative characteristics, including beauty, clarity, defects,

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demand, and rarity. Diamond pricing, in particular, is complex; values can vary significantly depending on time, place, and the subjective evaluations of buyers and sellers. There are more than 14,000 categories used to assess rough diamond and more than 100,000 different combinations of carat, clarity, color, and cut values used to assess polished diamond (Pearson, 1998).

Colored gemstone prices are generally influenced by market supply and demand considerations, and diamond prices are supported by producer controls on the quantity and quality of supply. Values and prices of gemstones produced and/or sold in the United States are listed in tables 3 through 5. In addition, customs values for diamonds and other gemstones imported, exported, or reexported are listed in tables 6 through 10.

De Beers Consolidated Mines Ltd. in South Africa is a significant force affecting gem diamond prices worldwide because it mines about one-half of the diamonds produced each year and sorts and values about two-thirds (by value) of the world's annual supply of rough diamonds through its Diamond Trading Co. (DTC), which has marketing agreements with other producers. Estimates based on the reported output of major diamond mines in 2000 indicate that the average value of all diamond produced during the year was about $71 per carat; by country, the average value per carat ranged from about $14 in Australia to more than $276 in Namibia (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm).

Foreign Trade

During 2000, total U.S. gemstone trade with all countries and territories exceeded $17.4 billion; diamonds accounted for about 92% of the total. In 2000, U.S. exports and reexports of diamond were shipped to 72 countries and territories, and imports of all gemstones were received from 112 countries and territories (tables 6-10).

During 2000, U.S. trade in cut diamonds reached unprecedented levels; the country continued to be the world's leading diamond importer and set export records as well. Record high imports were attributed to a relatively strong U.S. economy that boosted domestic demand for diamond jewelry among consumers with more personal wealth and discretionary income.

The United States is a significant international diamond transit center, as well as the world's largest gem diamond market. The large volume of reexports (table 6) shipped to other centers reveals the significance that the United States has in the world's diamond supply network.

Synthetic gemstone trade continued to increase for the United States in 2000. Imports of synthetic gems increased slightly during the year. Synthetic gemstone imports from Austria, China, Germany, Switzerland, and Thailand made up about 80% of the total domestic imports of synthetic gemstones during the year. Prices of certain synthetic gemstone imports, such as amethyst, were very competitive. The marketing of synthetic imports and enhanced gemstones as natural gemstones and the mixing of synthetic materials with natural stones in imported parcels continued to be problems for some domestic producers in 2000. Another problem during the year was that some simulants were being marketed as synthetic gemstones.

World Review

The gemstone industry worldwide has two distinct sectors: (1) diamond mining and marketing, and (2) the production and sale of colored gemstones. Most diamond supplies are controlled by a few major mining companies; prices are supported by managing the quantity and quality of the gemstones relative to demand, a function performed by De Beers through DTC. Unlike diamonds, colored gemstones are primarily produced at relatively small, low-cost operations with few dominant producers; prices are influenced by consumer demand in addition to supply availability.

In 2000, world diamond production totaled at least 118 million carats with an estimated value of more than $7.86 billion (table 11). Most production was concentrated in a few regions—Africa [Angola, Botswana, Congo (Kinshasa), Namibia, and South Africa], Asia (northeastern Siberia and Yakutia in Russia), Australia, North America (Northwest Territories in Canada), and South America (Brazil and Venezuela). In 2000, Botswana was the world's leading diamond producer in terms of output value and quantity (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm).

Global diamond sales hit a record high of $25.8 billion, nearly 9% higher than 1999, according to figures released by the Diamond High Council (CNN.com, January 30, 2001, Diamond sales enjoy record year, accessed February 2, 2001, at URL http://www.cnn.com/2001/WORLD/europe/01/30/belgium.diamonds/index.html). Record sales of rough diamond by DTC in 2000 reached $5.67 billion, 8.2% higher than the 1999 total of $5.24 billion. The sales record was primarily the result of very strong sales in the first half of the year. Sales in the second half of the year actually dropped by 23% compared with the second half of 1999 (The Diamond Registry, January 2001, U.S. market drives De Beers to record sales increase in 2000, accessed April 25, 2001, at URL http://www.diamondregistry.com/News/sales_record.htm). Retail diamond jewelry sales in the United States grew by 6% in 2000, the ninth consecutive year sales have risen (Diamond Registry Bulletin, 2001a).

Additional events significant to diamond mining and marketing worldwide in 2000 include the following:

- The Ekati Mine, Canada's first commercial diamond mine, completed its second full year of production. The Ekati Mine, located in the Northwest Territories, was a joint venture between BHP Diamonds Inc. (BHP) and Dia Met Minerals Ltd., but in June 2001, BHP purchased Dia Met Minerals Ltd. (BHP Diamonds Inc., 2001). Ekati has estimated reserves of 60.3 Mt of ore in kimberlite pipes, containing 54.3 million carats of diamonds, and the mine life is projected to be 25 years. In 2000, Ekati produced 2.63 million carats valued at $454 million, which reflected a record sales price of $172.52 per carat. Ekati diamonds are sold by the BHP sales office in Antwerp (65%) and by DTC (35%) (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm).
- The Diavik diamonds project is located in the Northwest Territories. Diavik has estimated reserves of 25.6 Mt of ore in kimberlite pipes, containing 102 million carats of diamonds, and the mine life is projected to be 20 years.

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Diavik received the required permits and regulatory approval in 2000 and began site infrastructure development and project construction. Diavik is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%), and it is expected to commence diamond production in the first half of 2003. The mine is expected to produce about 102 million carats of diamond at a rate of 6 million carats per year worth about $63 per carat (Diavik Diamond Mines Inc., 2000, p. 10-12).

- "Conflict diamonds" continued to partially finance warfare in Angola, Congo (Kinshasa), and Sierra Leone. In 2000, these "conflict diamonds" were discussed in the United Nations (U.N.), the U.S. Congress, the World Diamond Council, and the news media. The U.N. adopted a resolution on the role of diamonds in fueling conflict. A bill that was introduced, but not passed, in the 106th U.S. Congress would have required jewelry retailers to reveal the country of origin for all diamonds sold in the United States. In 2001, a revised version of this bill was reintroduced in the 107th U.S. Congress. The revised bill calls for a comprehensive diamond certification program and says that the United States can only import rough diamond from countries with the proper controls to ensure against importation of "conflict diamonds." "Conflict diamonds" were also the subject of much television and other media coverage in 2000. Despite all of this discussion and media attention, surveys indicate that during 2000, most diamond jewelry consumers did not ask for the country of origin when making their diamond buying decisions (Diamond Registry Bulletin, 2000a). One survey in 2000 indicated that 93% of consumers who were surveyed had never heard of "conflict diamonds," but 76% of consumers said that they would not purchase diamonds or diamond jewelry knowing that it came from a country where social injustice had occurred as a result of its production (Diamond Registry Bulletin, 2000c).
- De Beers Canada Mining Inc. acquired the Snap Lake diamond project from Winspear Diamonds Inc. and Aber Diamond Corp. in 2000. Snap Lake is located in the Northwest Territories and will be De Beers' first mine outside of southern Africa and the first underground diamond mine in Canada. Snap Lake has estimated reserves of 22.8 Mt of ore in a kimberlite dike, containing 38.8 million carats of diamonds, and the mine life is projected to be 20 years or more. Snap Lake is in its development phase and is scheduled to begin diamond production in the first half of 2003 (De Beers Canada Mining Inc., 2000, Snap Lake diamond project fact sheet, accessed June 13, 2001, at URL http://www.debeerscanada.com/files_new/snap/infrastruct.html).
- E-commerce in diamond and gemstone jewelry continued to grow during 2000. While more jewelry websites started operating online, many of the dot-com businesses overspent on advertizing and went out of business as a result. Preholiday season surveys indicated that the vast majority of 1999 online holiday customers also shopped online in 2000, and they spent more. The entire sum of online holiday sales, however, only amounted to about 1.5% of overall retail jewelry sales in 2000 (Diamond Registry Bulletin, 2000b).

Worldwide production of natural gemstones other than diamond was estimated to have exceeded $2 billion per year in the late 1990s. Most nondiamond gemstone mines are small, low-cost, and widely dispersed operations in remote regions of developing nations. Foreign countries with major gemstone deposits other than diamond are Afghanistan (beryl, ruby, and tourmaline); Australia (beryl, opal, and sapphire); Brazil (agate, amethyst, beryl, ruby, sapphire, topaz, and tourmaline); Burma (beryl, jade, ruby, sapphire, and topaz); Colombia (beryl, emerald, and sapphire); Kenya (beryl, garnet, and sapphire); Madagascar (beryl, rose quartz, sapphire, and tourmaline); Mexico (agate, opal, and topaz); Sri Lanka (beryl, ruby, sapphire, and topaz); Tanzania (garnet, ruby, sapphire, tanzanite, and tourmaline); and Zambia (amethyst and beryl). In addition, pearls are cultured throughout the South Pacific and in other equatorial waters; Australia, China, French Polynesia, and Japan are key producers.

Colored gemstone producers continued their recovery from the weakened markets created by the Asian economic crisis of 1997-98. Mining and sales reportedly were disrupted in many nations, particularly in Southeast Asia. Prices of high-quality colored gemstones, however, did not decline dramatically (Cavey, 1998).

Additional noteworthy items in the colored gemstone industry during 2000 included the following:

- Owing to the increased misuse of the terms like "synthetic" and "laboratory-created" in deceptive advertizing and owing to the proliferation of treatment processes to enhance gemstone attributes artificially without disclosure, the Federal Trade Commission has modified its "Guides for the Jewelry, Precious Metals, and Pewter Industries." The modified regulations went into effect April 10, 2001.
- During 2000, the popularity of colorful gemstones, colored synthetic gemstones, and "fancy" colored diamonds (even black diamonds) increased, as was evidenced by increased sales that are expected to continue in 2001 (Jewelers' Circular Keystone, 2000; Jewellery News Asia, 2000a, 2000c, 2001).

Outlook

It appears that the 2001 U.S. economy will not be a continuation of the good times we have enjoyed for the last few years. The U.S. diamond industry can take comfort in the fact that the value of their inventory is holding much better than the stock market (Diamond Registry Bulletin, 2001b). Historically, diamonds have proven to hold their value despite wars or depressions in the economy (Schumann, 1998, p. 8).

Diamond exploration is continuing in Canada, and many new deposits are being found. There have been additional discoveries in both the core and buffer zones of the Ekati lease. At least 35 kimberlites have been discovered in north-central Alberta, 70 large kimberlites have been found in Saskatchewan, and additional discoveries have been made in Ontario and Quebec (Luc Rombouts, Terraconsult bvba, May 2, 2001, Diamond annual review—2000, accessed June 19, 2001, at URL http://www.terraconsult.be/overview.htm). When the Diavik and Snap Lake mines begin production, Canada will be producing at least 15% to 20% of the total world diamond production.

Independent producers, such as Argyle Diamond Mines in Australia and new mines in Canada, will continue to bring a greater measure of competition to global markets. More competition presumably will bring more supplies and lower prices.

Numerous synthetics, simulants, and treated gemstones will enter the marketplace and necessitate more transparent trade

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industry standards to maintain customer confidence.

More diamonds, gemstones, and jewelry will be sold through online marketplaces and other forms of e-commerce that emerge to serve the diamond and gemstone industry. This will take place as the industry and its customers become more comfortable with and learn the best applications of new e-commerce tools for the gemstone industry (Authority on Jewelry Manufacturing, 2001).

References Cited

Authority on Jewelry Manufacturing, 2001, A net full of gemstones—The online gem marketplace expands: Authority on Jewelry Manufacturing, v. 46, no. 3, March, p. 23-29.

BHP Diamonds Inc., 2001, BHP acquires Dia Met: Vancouver, Canada, BHP Diamonds Inc. press release, June 20, p. 2.

Cavey, Christopher, 1998, Other gemstones: Mining Journal Annual Review Supplement, v. 330, no. 8481, May 22, p. 19.

Diamond Registry Bulletin, 1999, Verdict in—Crater of Diamonds remains public park: Diamond Registry Bulletin, v. 31, no. 2, February 28, p. 6.

———2000a, 2000—The year in which...: Diamond Registry Bulletin, v. 32, no. 11, December 31, p. 1.

———2000b, Diamonds, jewelry sell well online despite website closings: Diamond Registry Bulletin, v. 32, no. 10, November 30, p. 3.

———2000c, Keeping in mind a diamond's brighter side: Diamond Registry Bulletin, v. 32, no. 9, October 31, p. 1.

———2001a, 2000 U.S. diamond jewelry retail sales increase: Diamond Registry Bulletin, v. 33, no. 4, April 30, p. 3.

———2001b, The outlook for 2001: Diamond Registry Bulletin, v. 33, no. 1, January 31, p. 1.

Diavik Diamond Mines Inc., 2000, Diavik annual social and environmental report—2000: Yellowknife, Canada, Diavik Diamond Mines Inc., 74 p.

Howard, J.M., 1999, Summary of the 1990's exploration and testing of the Prairie Creek diamond-bearing lamproite complex, Pike County, AR, with a field guide, *in* Howard, J.M., ed., Contributions to the geology of Arkansas—Volume IV: Little Rock, AR, Arkansas Geological Commission, p. 57-73.

ICA Gazette, 1996, New survey measures U.S. jewelry market: ICA Gazette, August, 1 p.

Jewelers' Circular Keystone, 2000, Black by popular demand: Jewelers' Circular Keystone, v. 171, no. 10, October, p. 125-130.

Jewellery News Asia, 2000a, Coloured gemstones hot again in Asia: Jewellery News Asia, no. 185, January, p. 60-66.

———2000b, Supplier sees steady prices for shell nuclei: Jewellery News Asia, no. 188, April, p. 88-90.

———2000c, US synthetic coloured stones producer anticipates strong sales in Asia: Jewellery News Asia, no. 193, September, p. 196.

———2001, What's hot in 2001: Jewellery News Asia, no. 197, January, p. 49-56.

Pearson, Carl, 1998, Diamonds—The demand equation: Mining Journal, v. 331, no. 8505, November 6, p. 7.

Prost, M.A., 2001, Retail customers consume the classics: Colored Stone Magazine, v. 14, no. 1, January-February, p. 491-521.

Schumann, Walter, 1998, Gemstones of the world: New York, Sterling Publishing Company, Inc., p. 272.

U.S. International Trade Commission, 1997, Industry & trade summary—Gemstones: U.S. International Trade Commission Publication 3018, March, 72 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Area Reports: Domestic. Minerals Yearbook, annual.
Gem Stones. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Gemstones. Ch. in Mineral Commodity Summaries, annual.
Industrial Diamond. Ch. in Minerals Yearbook, annual.
Industrial Garnet. Ch. in Minerals Yearbook, annual.

Other

De Beers Consolidated Mines Ltd., annual report, 1998, 1999, 2000.
An Overview of Production of Specific U.S. Gemstones. Special Publication 14-95, U.S. Bureau of Mines, 1995.
Antwerp Confidential (monthly).
Basel Magazine (bimonthly).
Colored Stone Magazine (bimonthly).
Directory of Principal U.S. Gemstone Producers in 1995. Mineral Industry Surveys, U.S. Bureau of Mines, 1995.
Gems & Gemology (quarterly).
Gemstone Forecaster (quarterly).
Lapidary Journal (monthly).

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TABLE 1
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characters
Amber	Hydrocarbon	Yellow, red, green, blue	Any	Low to medium	2.0-2.5	1.0-1.1	Single	1.54	Synthetic or pressed plastics	Fossil resin, soft.
Benitoite	Barium titanium silicate	Blue, purple, pink, colorless	Small to medium	High	6.0-6.5	3.64-3.68	Double	1.76-1.80	Sapphire, tanzanite, blue diamond, blue tourmaline	Strong blue in ultraviolet light.
Beryl:										
Aquamarine	Beryllium aluminum silicate	Blue-green to light blue	Any	Medium to high	7.5-8.0	2.63-2.80	do.	1.58	Synthetic spinel, blue topaz	Double refraction, refractive index.
Bixbite	do.	do.	Small	Very high	7.5-8.0	2.63-2.80	do.	1.58	Pressed plastics, tourmaline	Refractive index.
Emerald	do.	Green	Medium	do.	7.5	2.63-2.80	do.	1.58	Fused emerald, glass, tourmaline, peridot, green garnet doublets	Emerald filter, dichroism, refractive index.
Emerald, synthetic	do.	do.	Small	High	7.5-8.0	2.63-2.80	do.	1.58	Genuine emerald	Flaws, brilliant, fluorescence in ultraviolet light.
Golden (heliodor)	do.	Yellow to golden	Any	Low to medium	7.5-8.0	2.63-2.80	do.	1.58	Citrine, topaz, glass, doublets	Weak-colored.
Goshenite	do.	do.	do.	Low	7.5-8.0	2.63-2.80	do.	1.58	Quartz, glass, white sapphire, white topaz	Refractive index.
Morganite	do.	Pink to rose	do.	do.	7.5-8.0	2.63-2.80	do.	1.58	Kunzite, tourmaline, pink sapphire	Do.
Calcite:										
Marble	Calcium carbonate	White, pink, red, blue, green, or brown	do.	do.	3.0	2.72	Double (strong)	1.49-1.66	Silicates, banded agate, alabaster gypsum	Translucent.
Mexican onyx	do.	do.	do.	do.	3.0	2.72	do.	1.60	do.	Banded, translucent.
Chrysoberyl:										
Alexandrite	Beryllium aluminate	Green by day, red by artificial light	Small (former U.S.S.R.)	High	8.5	3.50-3.84	Double	1.75	Synthetic	Dichroism, inclusions in synthetic sapphire.
Do.	do.	do.	Medium (Sri Lanka)	do.	8.5	3.50-3.84	do.	1.75	do.	Do.
Cats-eye	do.	Greenish to brownish	Small to large	do.	8.5	3.50-3.84	do.	1.75	Synthetic, shell	Gravity and translucence.
Chrysolite	do.	Yellow, green, and/or brown	Medium	Medium	8.5	3.50-3.84	do.	1.75	Tourmaline, peridot	Refractive index, silky.
Coral	Calcium carbonate	Orange, red, white, black, or green	Branching, medium	Low	3.5-4.0	2.6-2.7	do.	1.49-1.66	False coral	Dull translucent.
Corundum:										
Ruby	Aluminum oxide	Rose to deep purplish red	Small	Very high	9.0	3.95-4.10	do.	1.78	Synthetics, including spinel	Inclusions, fluorescence.
Sapphire	do.	Blue	Medium	High	9.0	3.95-4.10	do.	1.78	do.	Inclusions, double refraction, dichroism.
Sapphire, fancy	do.	Yellow, pink, white, orange, green, or violet	Medium to large	Medium	9.0	3.95-4.10	do.	1.78	Synthetics, glass and doublets	Inclusions, double refraction, refractive index.
Sapphire and ruby, stars	do.	Red, pink, violet, blue, or gray	do.	High to low	9.0	3.95-4.10	do.	1.78	Star quartz, synthetic stars	Shows asterism, color side view.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characters
Corundum:										
Sapphire or ruby, synthetic	Aluminum oxide	Yellow, pink, or blue	Up to 20 carats	Low	9.0	3.95-4.10	Double	1.78	Synthetic spinel, glass	Curved striae, bubble inclusions.
Diamond	Carbon	White, blue-white, yellow, brown, green, pink, blue	Any	Very high	10.0	3.516-3.525	Single	2.42	Zircon, titania, cubic zirconia	High index, dispersion, hardness, luster.
Feldspar:										
Amazonite	Alkali aluminum silicate	Green	Large	Low	6.0-6.5	2.56	XX	1.52	Jade	Cleavage, sheen, vitreous to pearly, opaque, grid.
Labradorite	do.	Gray with blue and bronze sheen color play	do.	do.	6.0-6.5	2.56	XX	1.56	do.	Do.
Moonstone	do.	Colorless or yellow	do.	do.	6.0-6.5	2.77	XX	1.52-1.54	Glass	Pale sheen, opalescent.
Garnet	Complex silicate	Brown, black, yellow, green, ruby red, or orange	Small to medium	Low to high	6.5-7.5	3.15-4.30	Single strained	1.79-1.98	Synthetics, spinel, glass	Single refraction, anomalous strain.
Jade:										
Jadeite	do.	Green, yellow, black, white, or mauve	Large	Low to very high	6.5-7.0	3.3-3.5	Crypto-crystalline	1.65-1.68	Onyx, bowenite, vesuvianite, grossularite	Luster, spectrum, translucent, to opaque.
Nephrite	Complex hydrous silicate	do.	do.	do.	6.0-6.5	2.96-3.10	do.	1.61-1.63	do.	Do.
Opal	Hydrous silica	Colors flash in white gray, black, red, or yellow	do.	Low to high	5.5-6.5	1.9-2.3	Single	1.45	Glass, synthetics, triplets	Play of color.
Pearl	Calcium carbonate	White, pink, or black	Small	do.	2.5-4.0	2.6-2.85	XX	XX	Cultured and imitation	Luster, structure, x ray.
Peridot	Iron magnesium silicate	Yellow and/or green	Any	Medium	6.5-7.0	3.27-3.37	Double (strong)	1.65-1.69	Tourmaline chrysoberyl	Strong double refraction, low dichroism.
Quartz:										
Agate	Silica	Any	Large	Low	7.0	2.58-2.64	XX	XX	Glass, plastic, Mexican onyx	Cryptocrystalline, irregularly banded, dendritic inclusions.
Amethyst	do.	Purple	do.	Medium	7.0	2.65-2.66	Double	1.55	do.	Refractive index, double refraction, transparent.
Cairngorm	do.	Smoky orange or yellow	do.	Low	7.0	2.65-2.66	do.	1.55	do.	Do.
Citrine	do.	Yellow	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Do.
Crystal, rock	do.	Colorless	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Do.
Jasper	do.	Any, striped, spotted, or sometimes uniform	do.	do.	7.0	2.58-2.66	XX	XX	do.	Opaque, vitreous.
Onyx	do.	Many colors	do.	do.	7.0	2.58-2.64	XX	XX	do.	Uniformly banded.
Rose	do.	Pink, rose red	do.	do.	7.0	2.65-2.66	Double	1.55	do.	Refractive index, double refraction, translucent.
Spinel	Magnesium aluminum oxide	Any	Small to medium	Medium	8.0	3.5-3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	do.	Up to 40 carats	Low	8.0	3.5-3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubbles.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characters
Spodumene:										
Hiddenite	Lithium aluminum silicate	Yellow to green	Medium	Medium	6.5-7.0	3.13-3.20	do.	1.66	Synthetic spinel	Refractive index.
Kunzite	do.	Pink to lilac	do.	do.	6.5-7.0	3.13-3.20	do.	1.66	Amethyst, morganite	Do.
Tanzanite	Complex silicate	Blue	Small	High	6.0-7.0	3.30	Double	1.69	Sapphire, synthetics	Strong trichroism.
Topaz	do.	White, blue, green	Medium	Low to medium	8.0	3.4-3.6	do.	1.62	Beryl, quartz	Refractive index.
Tourmaline	do.	Any, including mixed	do.	do.	7.0-7.5	2.98-3.20	do.	1.63	Peridot, beryl, corundum, glass	Double refraction, refractive index.
Turquoise	Copper aluminum phosphate	Blue to green	Large	Low	6.0	2.60-2.83	do.	1.63	Glass, plastics	Difficult if matrix not present, matrix usually limonitic.
Zircon	Zirconium silicate	White, blue, or brown, yellow, or green	Small to medium	Low to medium	6.0-7.5	4.0-4.8	Double (strong)	1.79-1.98	Diamond, synthetics, topaz, aquamarine	Double refraction, strongly dichroic, wear on facet edges.

XX Not applicable.
1/ Small: up to 5 carats; medium: 5 to 50 carats; large: more than 50 carats.
2/ Low: up to $25 per carat; medium: up to $200 per carat; high: more than $200 per carat.

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TABLE 2
SYNTHETIC GEMSTONE PRODUCTION METHODS

Gemstone	Production methods	Company/ producer	Date of first production
Alexandrite	Flux	Creative Crystals	1970s
Do.	Melt pulling	J.O. Crystal	1990s
Do.	do.	Kyocera	1980s
Do.	Zone melt	Seiko	1980s
Cubic zirconia	Skull melt	Various producers	1970s
Emerald	Flux	Chatham	1930s
Do.	do.	Gilson	1960s
Do.	do.	Kyocera	1970s
Do.	do.	Seiko	1980s
Do.	do.	Lennix	1980s
Do.	do.	Russia	1980s
Do.	Hydrothermal	Lechleitner	1960s
Do.	do.	Regency	1980s
Do.	do.	Biron	1980s
Do.	do.	Russia	1980s
Ruby	Flux	Chatham	1950s
Do.	do.	Kashan	1960s
Do.	do.	J.O. Crystal	1980s
Do.	do.	Douras	1990s
Do.	Zone melt	Seiko	1980s
Do.	Melt pulling	Kyocera	1970s
Do.	Verneuil	Various producers	1900s
Sapphire	Flux	Chatham	1970s
Do.	Zone melt	Seiko	1980s
Do.	Melt pulling	Kyocera	1980s
Do.	Verneuil	Various producers	1900s
Star ruby	do.	Linde	1940s
Do.	Melt pulling	Kyocera	1980s
Do.	do.	Nakazumi	1980s
Star sapphire	Verneuil	Linde	1940s

TABLE 3
VALUE OF U.S. GEMSTONE PRODUCTION, BY TYPE 1/

(Thousand dollars)

Gem materials	1999	2000
Agate	47 r/	(2/)
Beryl	3,360 e/	(2/)
Coral (all types)	54	(2/)
Diamond	(3/)	(3/)
Garnet	90	78
Gem feldspar	187	314
Geode/nodules	69	59
Jasper	49	30
Opal	147	219
Quartz	674	416
Sapphire/ruby	117	65
Shell	2,600	3,270
Topaz	8	8
Tourmaline	W	54
Turquoise	860	(2/)
Other	7,820	9,210
Total	16,100	17,200

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Included in "Total."
3/ Included with "Other."

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TABLE 4
PRICES OF U.S. CUT DIAMONDS, BY SIZE AND QUALITY 1/

Carat weight	Description, color 3/	Clarity 2/ (GIA terms)	Representative prices January 2000 4/	June 2000 5/	December 2000 6/
0.25	G	VS1	$1,500	$1,500	$1,500
.25	G	VS2	1,380	1,380	1,380
.25	G	SI1	1,130	1,130	1,130
.25	H	VS1	1,400	1,400	1,400
.25	H	VS2	1,250	1,250	1,250
.25	H	SI1	1,050	1,050	1,050
.50	G	VS1	3,400	3,400	3,400
.50	G	VS2	3,000	3,000	3,000
.50	G	SI1	2,500	2,500	2,500
.50	H	VS1	3,000	3,000	3,000
.50	H	VS2	2,700	2,700	2,700
.50	H	SI1	2,400	2,400	2,400
.75	G	VS1	3,800	3,800	3,800
.75	G	VS2	3,600	3,600	3,600
.75	G	SI1	3,300	3,300	3,300
.75	H	VS1	3,650	3,650	3,650
.75	H	VS2	3,450	3,450	3,450
.75	H	SI1	3,100	3,100	3,100
1.00	G	VS1	5,700	5,800	5,900
1.00	G	VS2	5,300	5,400	5,700
1.00	G	SI1	4,800	4,900	5,000
1.00	H	VS1	5,200	5,300	5,500
1.00	H	VS2	4,900	5,000	5,300
1.00	H	SI1	4,500	4,600	4,800

1/ Data are rounded to no more than three significant digits.
2/ Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; G, H, I— traces of color
3/ Clarity: IF—no blemishes; VVS1—very, very slightly included; VS1—very slightly included; VS2—very slightly included, but not visible; SI1—slightly included.
4/ Source: Jewelers' Circular Keystone, v. 171, no. 2, February 2000, p. 58.
5/ Source: Jewelers' Circular Keystone, v. 171, no. 7, July 2000, p. 46.
6/ Source: Jewelers' Circular Keystone, v. 172, no. 1, January 2001, p. 52.

TABLE 5
PRICES PER CARAT OF U.S. CUT COLORED GEMSTONES

Gemstone	Price range per carat January 2000 1/	December 2000 2/
Amethyst	$7-$14	$7-$14
Aquamarine	75-200	75-250
Emerald	1,000-2,400	1,000-2,400
Ruby	1,800-2,800	1,800-2,800
Sapphire	650-1,800	450-1,450
Tanzanite	250-350	325-400

1/ Source: Jewelers' Circular Keystone, v. 171, no. 2, February 2000, p. 58. Amethyst and aquamarine prices are from The Guide, Spring/Summer 2000, p. 12, 72. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged their cash customers during the month for fine-quality stones.
2/ Source: Jewelers' Circular Keystone, v. 172, no. 1, January 2001, p. 52. Amethyst, aquamarine, and tanzanite prices are from The Guide, Fall/Winter 2000-2001, p. 12, 72, 104. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged their cash customers during the month for fine-quality stones.

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TABLE 6
U.S. EXPORTS AND REEXPORTS OF DIAMOND (EXCLUSIVE OF INDUSTRIAL DIAMOND), BY COUNTRY 1/

Country	1999 Quantity (carats)	1999 Value 2/ (millions)	2000 Quantity (carats)	2000 Value 2/ (millions)
Exports:				
Belgium	9,260	$10	114,000	$248
Canada	81,700	30	123,000	39
France	16,700	10	30,300	67
Hong Kong	29,600	34	111,000	150
India	56,200	13	109,000	36
Israel	14,600	28	268,000	354
Japan	5,460	22	23,100	60
Singapore	11,400	5	15,000	14
Switzerland	42,000	79	73,100	143
Thailand	102	1	13,100	12
United Arab Emirates	1,360	3	1,540	6
United Kingdom	20,200	21	74,600	64
Other	199,000	47	319,000	89
Total	487,000	303	1,270,000	1,280
Reexports:				
Belgium	980,000	669	3,850,000	666
Canada	97,400	41	105,000	49
France	40,800	40	75,100	21
Hong Kong	822,000	308	3,260,000	396
India	902,000	134	600,000	79
Israel	1,120,000	1,020	4,770,000	1,010
Japan	109,000	62	259,000	34
Singapore	43,100	27	259,000	32
Switzerland	184,000	265	477,000	187
Thailand	177,000	22	247,000	28
United Arab Emirates	25,300	10	72,100	13
United Kingdom	111,000	97	455,000	94
Other	346,000	75	551,000	89
Total	4,950,000	2,770	15,000,000	2,700
Grand total	5,440,000	3,080	16,300,000	3,980

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY 1/

Kind, range, and country of origin	1999 Quantity (carat)	1999 Value 2/ (millions)	2000 Quantity (carat)	2000 Value 2/ (millions)
Rough or uncut, natural: 3/				
Australia	945	$1	12	(4/)
Belgium	118,000	121	431,000	$190
Brazil	11,600	5	29,500	9
Congo (Brazzaville)	25,500	2	7,860	15
Congo (Kinshasa)	53,200	74	2,290	10
Ghana	110,000	102	699,000	36
Guinea	10,100	16	4,390	8
India	18,600	(4/)	276,000	(4/)
Israel	38,000	25	19,200	20
Russia	3,080,000	4	4,240	1
Sierra Leone	4,420	6	668	1
South Africa	40,500	73	136,000	194
Switzerland	2,520	18	5,200	23
United Kingdom	663,000	229	538,000	185
Venezuela	3,290	1	6,870	2

See footnotes at end of table.

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TABLE 7--Continued
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY 1/

Kind, range, and country of origin	1999 Quantity (carat)	1999 Value 2/ (millions)	2000 Quantity (carat)	2000 Value 2/ (millions)
Rough or uncut, natural--Continued: 3/				
Other	88,900	$56	116,000	$47
Total	4,270,000	734	2,280,000	741
Cut but unset, not more than 0.5 carat:				
Belgium	771,000	208	769,000	221
Brazil	3,720	2	13,400	3
Canada	1,260	1	2,070	1
Germany	6,290	1	4,590	1
Hong Kong	289,000	47	466,000	79
India	12,400,000	1,900	11,600,000	2,050
Israel	1,080,000	608	1,150,000	693
Japan	12,100	3	3,950	2
South Africa	3,280	3	1,480	2
Switzerland	36,400	10	133,000	9
Thailand	103,000	14	127,000	18
United Kingdom	1,650	1	11,700	3
Other	245,000	42	217,000	42
Total	14,900,000	2,840	14,500,000	3,120
Cut but unset, more than 0.5 carat:				
Belgium	1,030,000	1,630	1,330,000	2,170
Botswana	--	--	2	(4/)
Canada	1,780	6	2,830	9
France	2,530	6	2,110	16
Hong Kong	81,000	117	105,000	139
India	664,000	383	639,000	461
Israel	2,290,000	3,650	2,740,000	4,630
Japan	1,910	7	14,800	13
Russia	29,000	44	45,100	61
Singapore	2,210	7	4,180	14
South Africa	24,800	67	34,100	140
Switzerland	35,100	254	34,200	263
Thailand	16,700	18	23,800	27
United Kingdom	20,800	75	22,100	100
Other	34,100	55	48,500	90
Total	4,230,000	6,320	5,040,000	8,140

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Includes some natural advanced diamond.
4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY 1/

Kind and country	1999 Quantity (carats)	1999 Value 2/ (millions)	2000 Quantity (carats)	2000 Value 2/ (millions)
Emerald:				
Belgium	14,000	$2	10,600	$2
Brazil	601,000	6	6,750,000	8
Canada	803	(3/)	1,120	1
China	955	(3/)	1,060	(3/)
Colombia	601,000	59	11,300,000	66
France	7,040	1	3,180	1
Germany	25,800	3	40,700	2
Hong Kong	252,000	10	240,000	9
India	2,860,000	35	3,110,000	32

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND,

BY KIND AND COUNTRY 1/

Kind and country	1999 Quantity (carats)	1999 Value 2/ (millions)	2000 Quantity (carats)	2000 Value 2/ (millions)
Emerald--Continued:				
Israel	272,000	$26	181,000	$30
Japan	8,370	(3/)	48	(3/)
South Africa	183	(3/)	78	(3/)
Switzerland	34,300	27	137,000	15
Taiwan	3,760	(3/)	526	(3/)
Thailand	201,000	4	258,000	4
United Kingdom	52,800	3	3,630	1
Other	102,000	6	76,400	5
Total	5,040,000	183	22,100,000	176
Ruby:				
Belgium	6,120	1	2,120	1
Brazil	7,350	(3/)	6,020	(3/)
Burma	4,290	14	55,900	4
Canada	373	(3/)	120	(3/)
China	3,260	(3/)	1,170	(3/)
Colombia	2,140	(3/)	1,840	(3/)
France	1,790	(3/)	1,710	(3/)
Germany	54,400	7	16,300	1
Hong Kong	270,000	6	253,000	10
India	1,320,000	4	1,600,000	5
Israel	24,000	3	37,800	3
Japan	3,160	(3/)	9,280	(3/)
Switzerland	46,200	20	32,100	7
Thailand	2,250,000	48	2,450,000	46
United Kingdom	29,300	3	5,590	4
Other	59,800	2	31,200	4
Total	4,080,000	110	4,500,000	85
Sapphire:				
Australia	8,540	(3/)	7,320	1
Belgium	12,500	2	3,000	1
Brazil	6,920	(3/)	6,590	(3/)
Burma	1,830	2	8,720	2
Canada	44	(3/)	699	1
China	15,200	(3/)	30,000	(3/)
Colombia	2,110	(3/)	43,100	(3/)
France	815	(3/)	1,740	1
Germany	143,000	3	53,700	1
Hong Kong	301,000	9	326,000	11
India	862,000	3	1,160,000	4
Israel	100,000	6	63,100	5
Japan	16,300	(3/)	105,000	1
Singapore	285	(3/)	147	(3/)
Sri Lanka	480,000	19	492,000	25
Switzerland	38,600	15	50,400	17
Tanzania	822	(3/)	238	(3/)
Thailand	5,080,000	64	6,000,000	81
United Kingdom	14,100	4	13,800	3
Other	81,700	2	28,900	4
Total	7,160,000	129	8,400,000	156
Other:				
Rough, uncut:				
Australia	NA	4	NA	4
Brazil	NA	26	NA	15
China	NA	1	NA	1
Colombia	NA	2	NA	2
Fiji	NA	2	NA	2
Hong Kong	NA	1	NA	1
India	NA	1	NA	1
Kenya	NA	(3/)	NA	(3/)
Nigeria	NA	(3/)	NA	(3/)
Pakistan	NA	(3/)	NA	1

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY 1/

Kind and country	1999 Quantity (carats)	1999 Value 2/ (millions)	2000 Quantity (carats)	2000 Value 2/ (millions)
Other--Continued:				
Rough, uncut--Continued:				
Philippines	NA	$1	NA	$1
Russia	NA	(3/)	NA	(3/)
South Africa	NA	1	NA	2
Switzerland	NA	(3/)	NA	(3/)
Taiwan	NA	(3/)	NA	(3/)
Tanzania	NA	(3/)	NA	1
Thailand	NA	7	NA	11
United Kingdom	NA	(3/)	NA	1
Zambia	NA	2	NA	5
Other	NA	11	NA	9
Total	NA	57	NA	56
Cut, set and unset:				
Australia	NA	8	NA	18
Brazil	NA	10	NA	10
Canada	NA	1	NA	1
China	NA	11	NA	13
French Polynesia	NA	5	NA	5
Germany	NA	14	NA	17
Hong Kong	NA	44	NA	56
India	NA	66	NA	81
Israel	NA	6	NA	11
Japan	NA	16	NA	10
Kenya	NA	2	NA	1
Sri Lanka	NA	3	NA	6
Switzerland	NA	2	NA	3
Taiwan	NA	3	NA	2
Tanzania	NA	8	NA	13
Thailand	NA	30	NA	33
United Kingdom	NA	6	NA	6
Other	NA	7	NA	9
Total	NA	243	NA	294

NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEMSTONES, BY COUNTRY 1/

(Thousand dollars) 2/

Country	1999	2000
Synthetic, cut but unset:		
Australia	488	97
Austria	7,180	6,670
Brazil	2,110	136
China	13,300	13,500
France	500	1,020
Germany	10,500	10,300
Hong Kong	2,110	2,990
India	971	795
Italy	104	289
Japan	6	69
Korea, Republic of	2,720	2,510

See footnotes at end of table.

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TABLE 9--Continued
VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEMSTONES, BY COUNTRY 1/

(Thousand dollars) 2/

Country	1999	2000
Synthetic, cut but unset--Continued:		
Spain	39	10
Sri Lanka	89	612
Switzerland	4,260	6,410
Taiwan	828	708
Thailand	4,490	3,820
Other	331	1,000
Total	50,100	50,900
Imitation: 3/		
Austria	50,800	59,100
China	1,180	990
Czech Republic	11,700	11,200
Germany	1,710	1,250
Japan	495	756
Spain	36	45
Taiwan	336	274
Other	1,090	2,580
Total	67,300	76,200

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Includes pearls.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES 1/

(Thousand carats and thousand dollars)

Stones	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Diamonds:				
Rough or uncut	4,270	734,000	2,280	741,000
Cut but unset	19,200	9,160,000	19,500	11,300,000
Emeralds, cut but unset	5,040	183,000	22,100	176,000
Coral and similar materials, unworked	NA	7,090	NA	8,920
Rubies and sapphires, cut but unset	11,200	239,000	12,900	241,000
Pearls:				
Natural	NA	2,120	NA	960
Cultured	NA	44,800	NA	46,100
Imitation	NA	1,420	NA	2,020
Other precious and semiprecious stones:				
Rough, uncut	1,330,000	43,500	1,070,000	39,400
Cut, set and unset	NA	196,000	NA	247,000
Other	NA	6,110	NA	7,840
Synthetic:				
Cut but unset	287,000	50,100	329,000	50,900
Other	NA	7,370	NA	6,190
Imitation gemstone 3/	NA	65,900	NA	74,200
Total	XX	10,700,000	XX	12,900,000

NA Not available. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Does not include pearls.

Source: U.S. Census Bureau.

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TABLE 11
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1996	1997	1998	1999	2000
Gemstones: 3/					
Angola	2,250	1,110	2,400	3,700 r/	5,400
Australia	18,897 4/	18,100	18,400	13,403 4/	12,014 4/
Botswana	12,388 r/ 4/	15,111 r/ 4/	14,772 r/ 4/	16,000 r/	19,700
Brazil	200	300	300	300	300
Canada	--	--	300	2,000	2,000
Central African Republic	350	400	330	400	400
China	230	230	230	230	230
Congo (Kinshasa)	3,300 r/	3,300 r/	5,080 r/	4,120 r/	3,500
Cote d' Ivoire	202	207	210	210	200
Ghana	142	664	649	518 r/	178
Guinea	165	165	300	410 r/	410
Liberia	60	80	150	120 r/	120
Namibia	1,402 4/	1,350 r/	1,390 r/	1,550 r/	1,520
Russia	10,500	11,200 r/	11,500	11,500	11,600
Sierra Leone	162 4/	300	200	450 r/	450
South Africa	4,400	4,500	4,300	4,000	4,300
Venezuela	99	158	80 r/	59 r/	60
Zimbabwe	300	321	10	15 r/	7
Other	165	124 r/	106	207 r/	258
Total	55,200 r/	57,600 r/	60,800 r/	59,200 r/	62,600
Industrial:					
Angola	250	124	364	400 r/	600
Australia	23,096 4/	22,100	22,500	16,381 4/	14,684 4/
Botswana	5,000	5,000	5,000	5,350 r/	4,950
Brazil	600	600	600	600	600
Central African Republic	120	100	200	150	150
China	900	900	900	920	920
Congo (Kinshasa)	18,940 r/ 4/	18,677 r/ 4/	21,000 r/	16,000 r/	14,200
Cote d' Ivoire	100	100	100	100	100
Ghana	573	166	160	128 r/	712
Guinea	40	40	100	140 r/	140
Liberia	90	120	150	80 r/	80
Namibia	--	71	73	89 r/	80
Russia	10,500	11,200 r/	11,500	11,500	11,600
Sierra Leone	108	100	50	150 r/	150
South Africa	5,550	5,540	6,460	6,020 r/	6,480
Venezuela	73	90	17 r/	36 r/	40
Zimbabwe	137	100	19	30 r/	13
Other	120	105	97	141 r/	143
Total	66,200 r/	65,100 r/	69,300 r/	58,200 r/	55,600
Grand total	121,000 r/	123,000 r/	130,000 r/	117,000 r/	118,000

r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 25, 2001.

3/ Includes near- and cheap-gem qualities.

4/ Reported figure.

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GERMANIUM

By Robert D. Brown, Jr.

Domestic survey data and tables were prepared by Carolyn F. Crews, statistical assistant.

Germanium, a grayish-white element, is a semiconductor, with electrical characteristics between those of a metal and an insulator. It is commercially available as a tetrachloride and a high-purity oxide and in the form of metal ingots, single-crystal bars, castings, doped semiconductors, optical materials, optical blanks, and other specialty products. Germanium is used principally in fiber optics, infrared optics, and polymerization catalysts. Its special mechanical, optical, and electrical properties, as well as its moderate cost, also make it attractive in many aerospace applications.

In 2000, the domestic germanium industry consisted of two zinc mining operations in Alaska and Tennessee, which supplied byproduct germanium concentrates for export, and three refineries in New York, Oklahoma, and Pennsylvania. The domestic refineries processed manufacturers' scrap, imported semirefined materials, and some old (postconsumer) scrap. Domestic refinery production, which amounted to slightly less than one-third of world refinery output, was estimated to be valued at $29 million. Domestic refinery production and consumption for germanium are estimated by the U.S. Geological Survey (USGS) on the basis of discussions with domestic producers. Both domestic refinery production and U.S. consumption of germanium were estimated to have increased in 2000.

The USGS estimated domestic germanium reserves to be 450,000 kilograms (kg), equivalent to 15 years of domestic consumption at the 2000 rate; figures for worldwide reserves were not available. Worldwide, germanium resources are associated with zinc and lead-zinc-copper sulfide ores.

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984, with an initial goal of 30,000 kg of germanium metal. In 1987, a new NDS goal of 146,000 kg was established; in 1991, this was adjusted downward to 68,198 kg. In 1995, the Defense Logistics Agency (DLA), which maintains the NDS, made plans to sell germanium at a rate of 4,000 kilograms per year (kg/yr) through 2005. This proposed rate remained the same for 1996, but it was increased to 6,000 kg/yr in 1997 and to 8,000 kg/yr in 1998. All the material offered is zone-refined polycrystalline germanium metal (U.S. Department of Defense, 1997). The amount designated for annual sales was a significant portion of the domestic and world market, but in most years less than the amount available for sale has been sold.

At the current stockpile disposal rate, the DLA price has become not only a good indicator of the market value of germanium, but also a factor in determining that value. Sales began in 2000 at just under $1,000 per kilogram and fell gradually to $870 per kilogram during the year (Mining Journal, 2000b). After 2,843 kg was sold in 2000, the yearend inventory was 48,531 kg of germanium metal. The main factor resulting in the price decrease was a continued slowdown in the implementation of satellite communication systems in spite of brisk demand in other use sectors.

Production

In 2000, the USGS estimated U.S. refinery production of germanium from primary and semirefined materials to be 23,000 kg, 15% more than that of 1999. The Electro-Optic Materials Department of Eagle-Picher Industries, Inc., in Quapaw, OK, remained the largest domestic producer in 2000, producing germanium from reprocessed scrap, fly ash, germanium concentrates (typically containing 5% or more germanium), and semirefined germanium materials.

Cabot Corp., Revere, PA, and Atomergic Chemetals Corp., Plainview, NY, produced germanium from reprocessed scrap and semirefined foreign material. The zinc refinery at Clarksville, TN, owned by Savage Resources Ltd., continued to produce germanium-rich residues as a byproduct of processing zinc ores from its associated Elmwood-Gordonsville Mine. Savage has continued the established practice of shipping these residues to Union Minière, SA's Electro-Optic Materials Business Unit in Belgium for germanium recovery and refining.

Consumption

The USGS estimates that domestic consumption of germanium in 2000 increased to approximately 28,000 kg. The domestic use pattern was similar to the world use pattern, which was estimated to be as follows: fiber optics, 50%; polymerization catalysts, 25%; infrared optics, 15%; electrical/solar applications, 5%; and other uses (as phosphors, in metallurgy, and in chemotherapy), 5%. The major difference between the domestic and world patterns of consumption is that the greatest U.S. germanium demand is for fiber optics, while in Japan most of the germanium is used for polymerization catalysts (Roskill's Letter from Japan, 1999).

In the fiber optics sector, germanium was used as a dopant within the core of optical fiber used by the telecommunications industry. Because germanium lenses and windows are transparent to infrared radiation, they can be used in infrared optical systems in the same ways that ordinary glass lenses and windows are used in visible light optical systems. These optics have been used principally for military guidance and weapon-sighting applications. Germanium glass was also used for nonmilitary surveillance, night vision, and monitoring systems in a wide range of fields, including satellite systems and fire alarms.

A significant factor influencing germanium consumption in 2000 involved satellite communication systems. Satellite launch delays at the Teledesic Project, which is to be a large satellite based communications system, resulted in a decline in solar cell manufacture. This project, when restarted, would require about 12,000 kg of germanium for solar cells (Mining Journal, 2000a). The decline in consumption for solar cell applications was overcome by increases in other sectors in 2000. The use of germanium as a dopant in optical fibers continued to grow.

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General Motors Corp. began incorporating a germanium-based night vision system in its top-of-the-line cars. Several manufacturers have begun production of SiGe chips.

Prices

In 1995, domestic producer prices for germanium metal and dioxide were, for the first time, set higher than the longstanding price levels established in late 1981 ($1,060 and $660 per kilogram, respectively). Throughout the 1981-1995 period, producers significantly discounted prices in response to competition from imported materials. In 1995 and 1996, however, producer prices for zone refined metal reportedly reached $1,375 and $2,000 per kilogram, respectively; germanium dioxide producer prices rose to $880 and $1,300 per kilogram, respectively. In 1997, the producer prices fell back to $1,475 per kilogram for the metal and $950 per kilogram for the dioxide. In 1998, they increased again to $1,700 per kilogram for the metal and $1,100 per kilogram for the dioxide. In 1999, the prices were reduced to $1,400 and $900 per kilogram, respectively, owing to sluggish demand. In 2000, prices continued to fall, reaching $1,250 and $800 per kilogram, respectively, mainly due to plentiful supply rather than lack of demand.

Free market prices for germanium dioxide, published by Metal Bulletin, began 2000 in the $680 to $750 per kilogram range and ended the year in the $620 to $700 range. The price for Belgian-produced germanium dioxide, published by Metal Bulletin, remained at $750 per kilogram all year.

In 1998, germanium prices increased despite an oversupply that resulted from: (1) slight decreases in world demand for optical fibers and polyethylene terephthalate (PET); and (2) an increase in total supply owing to greater amounts of recycling and continued releases of germanium from national stockpiles in Russia, Ukraine, and the United States. This increase in price was probably due to anticipated demand in the satellite communications sector, and, when this increase in demand did not occur in 1999, germanium prices began to fall. This same mechanism prevailed in 2000. Demand in satellite applications did not increase, and prices continued to fall.

Trade

In 2000, the estimated germanium content of imports was approximately 8,210 kg, compared with 12,400 kg in 1999. China, Belgium, and Russia, in descending order of shipments, accounted for approximately 87% of U.S. germanium imports in 2000 (table 1). Imports directly attributable to China and countries of the former Soviet Union amounted to about 53% of the total. Trade reliance on large shipments from these countries began in the early 1990s.

World Review

In 2000, world refinery production of primary germanium was estimated to be slightly more than 70,000 kg, an increase of more than 20% from that of 1999. Recycling supplied 25,000 kg of germanium worldwide, the same as in 1999. The world total market supply was about 105,000 kg in 2000, counting 3,000 kg released from the U.S. NDS and 6,000 kg taken from non-Government stockpiles. World consumption matched the total supply. This exceeded production, but supply was made adequate owing to the amounts gained from recycling and stockpile releases. World consumption for 2000 was 19% higher than that in 1999.

Austria.—Austria Mikro Systeme International AG is constructing a modern facility for the production of application-specific integrated circuits and application-specific standard products, including silicon-germanium devices. These products will be for automotive, communication, and industrial applications. The budget for the construction of the new production line is 305 million euro (Austria Mikro Systeme International AG, 2000).

Belgium.—Union Minière, SA, Brussels, made nearly $16 million profit when it sold its share of EMCORE Corp., a semiconductor technology company with headquarters in Somerset, NJ. A joint venture between the two companies to develop new applications for germanium-based components and supply germanium substrates for space solar cells will continue (American Metal Market Online, March 3, 2000, UM posts profit on EMCORE stake sale, accessed March 17, 2000, via URL http://www.AMM.com).

China.—The Nei Mongol Coalfield Geology Bureau has discovered a large germanium deposit at Xilinhaote in Nei Mongol. The germanium contained in the deposit is estimated to be up to 1,600 metric tons, which would make it account for 30% of China's reserves. It is a paragenetic coal/germanium deposit, the largest in China. It would be amenable to large scale open pit mining (Engineering and Mining Journal, 1999). China is the leading supplier of germanium to the United States, accounting for 42% of germanium imports in 1999 and 40% in 2000. China is also a leading supplier of germanium oxide to Japan for use in the production of PET bottles. China provided more than one third of Japanese imported germanium oxide in 1999.

Germany—PPM Pure Metals AG, a subsidiary of Metaleurop GmbH, produces many high-purity metals and compounds including germanium oxide for use as a polymerization catalyst in the production of PET polymer and as a reflective dopant in the core of optical fibers. The company expects to grow with the expanding germanium market (Karpel, 2000).

Current Research and Technology

Germanium is being used for the optics in night vision systems that utilize infrared rays. The germanium lens focuses the infrared rays from the object observed to a detector. All objects emit heat to some degree, but humans, animals, and moving vehicles are quite visible in the infrared spectrum because of the large contrast of emission from the object compared to its background. General Motors installed these systems called night vision, manufactured by Raytheon Corp., on its Cadillac DeVille model in 2000 (Siuru, 1999). Cadillac predicted sales of 3,500 units in 2000, but then asked Raytheon to quadruple production. In its first year, 7,000 of the night vision systems were installed, with Cadillac dealers demanding more. It is expected that production will double again in 2001. Currently the device adds about $2,000 to the cost of the DeVille. High-volume production could cut the cost in half (Truett, 2001). The night vision segment of the surveillance market is expected to grow from $560 million in 1999 to $750 million by 2004 (Hindus, 2000).

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Silicon-germanium (SiGe) technology is poised for growth. With the proven viability of implanting silicon with germanium to produce transistors, a number of manufacturers have begun production (Bindra, 2000). By depositing a layer of germanium onto the silicon, one can engineer the energy band structure, the band gap, electron mobilities, and numerous other properties while using conventional silicon processing (Paul, 2000). The only additional step is the actual deposition of the germanium. The cost of this kind of processing is proportional to the number of steps; since 10 to 30 steps are typically involved in the fabrication of a chip, however, the one extra step increases the cost very little (Pool, 2001). SiGe chips combine the high speed properties of germanium with the low cost, well established production techniques of the silicon-chip industry. Most semiconductor technologies that use more than one material are complicated because of the physical and chemical differences between the components. Because silicon and germanium are fairly similar, SiGe processing can be relatively simple.

SiGe also requires less power to perform the same function as its silicon counterpart (Pool, 2001). Thus, SiGe has great potential for mobile phone applications because talk time or battery life is very important in wireless communication. SiGe is expected to provide faster, smaller, and cheaper microchips for third generation mobile phones (Pool, 2001). Gallium arsenide also may be vulnerable to substitution by SiGe in microwave devices (Metal Bulletin, 2000). Strategies Unlimited, a market analysis firm, has predicted that the market for SiGe wireless and digital applications will reach $1.8 billion by 2005 (Paul, 2000).

Outlook

Expected demand increases for fiber optics and new uses could fuel a drive for the development of new germanium resources. The industry appears poised for expansion in spite of recent lackluster price performance (Karpel, 2000). Balancing mechanisms of stockpile releases and increased recycling have thus far tended to hold prices down in spite of increasing demand. Further, even significant increases in demand do not drive prices up if these increases are somewhat less than expected. Greater volatility in the germanium market, however, could occur during the next few years if stockpiles and recycling cannot adequately balance supply and rising demand.

References Cited

Austria Mikro Systeme International AG, 2000, Austria Mikro Systeme invests EUR 305 million into construction of new production line: Unterpremstäten, Austria, Austria Mikro Systeme International AG press release, March 24, 1 p.

Bindra, Ashok, 2000, Silicon-germanium technology is ready for prime time: Electronic Design, v. 48, no. 14, July 10, p. 62.

Engineering and Mining Journal, 1999, China: Engineering and Mining Journal, v. 200, no. 5, May, p. 14.

Hindus, Leonard, 2000, New estimate—U.S. night vision surveillance devices to pass $750 million by 2004: Advanced Imaging, v. 15, no. 4, April, p. 38.

Karpel, Steve, 2000, Metals pure and simple: Metal Bulletin Monthly, no. 357, September, p. 49-53.

Metal Bulletin, 2000, Gallium production set to meet rising demand: Metal Bulletin, no. 8477, May 22, p. 11.

Mining Journal, 2000a, Minor metals end year with a whimper: Mining Journal, v. 334, no. 8564, January 7, p. 10.

———2000b, Minor metals in November: Mining Journal, v. 335, no. 8612, December 8, p. 459.

Paul, D.J., 2000, The physics, material and devices of silicon-germanium technology: Physics World, v. 13, no. 2, February, p. 27-32.

Pool, Rebecca, 2001, SiGe enters race for 3G chips: Ottawa, Canada, SiGe Microsystems press release, March, 2 p.

Roskill's Letter from Japan, 1999, Germanium—Changes in the germanium dioxide catalyst market: Roskill's Letter from Japan, no. 279, July, p. 14-16.

Siuru, Bill, 1999, Night vision for your car: Electronics Now, v. 70, no. 6, p. 31-32.

Truett, Ray, 2001, Raytheon cranks up night vision production: Automotive News, v. 75, no. 5920, p. 24.

U.S. Department of Defense, 1997, Strategic and critical materials report to the Congress: Washington, DC, U.S. Department of Defense, January 15, 48 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Germanium. Ch. in Mineral Commodity Summaries, annual.
Germanium. Ch. in Minerals Yearbook, annual.
Gallium, Germanium, and Indium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Germanium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platt's Metals Week.

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TABLE 1
U.S. IMPORT OF GERMANIUM, BY CLASS AND COUNTRY 1/

Class and country	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Wrought, unwrought, waste, and scrap:				
Belgium	1,620	$2,740,000	3,030	$3,940,000
Canada	8	8,000 r/	77	51,700
China	5,210	4,680,000 r/	3,290	3,450,000
France	--	--	1	3,050
Germany	136	89,100	342	364,000
Israel	160	257,000	70	101,000
Japan	124	13,900	316	268,000
Netherlands	4	2,250	3	4,840
Russia	1,100	684,000	857	805,000
Taiwan	2,490	84,100	--	--
Ukraine	1,210	1,470,000	176	166,000
United Kingdom	382	411,000	53	84,600
Total	12,400	10,400,000	8,210	9,240,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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GOLD

By Earle B. Amey

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Domestic gold mine production in 2000 was midway between the alltime high record reached in 1998 and what was produced in 1999. Primarily, the 3.5% improvement over the 1999 level was the result of more stable gold prices and the weakening of the United States dollar. The United States has been the second largest gold producer (behind South Africa) since 1991, when U.S. production surpassed that of the Soviet Union for the first time in five decades. Nevada produced more than three-fourths of domestic production; the remaining output came from 10 other States. Gold was produced at 64 lode mines; about a dozen large placer mines, all in Alaska; and numerous small placer mines, mostly in Alaska and the Western States. In addition, a small amount of domestic gold was produced as a byproduct of processing base metals, principally copper. Thirty mines yielded almost 97% of the gold produced in the United States. The value of U.S. gold mine production was about $3.2 billion in 2000.

Domestic gold exploration activity dropped on a total dollar basis for the third consecutive year, declining from $194.5 million in 1999 to $183.4 million in 2000. The percentage of the total world gold exploration budget going to the United States, however, increased by 16.8% in 2000 for the third time because U.S. companies spent proportionately more on gold as worldwide gold exploration expenditures dropped by 7% from 1999, by 24% from 1998, and by 29% from 1997 (diGesu and others, 2000b).

Commercial-grade refined gold came from about two dozen domestic producers. Of several thousand companies and artisans, a few dozen companies dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and the Providence, RI, areas, with other concentrations in California, Florida, and Texas. In 2000, estimated end uses of gold were jewelry and arts, 89%; dental, 7%; and electrical and electronics, 4%. According to the World Gold Council (2001, p. 2), 2000 was the 10th consecutive year of unit sales increases for gold jewelry in the United States. Total U.S. gold jewelry sales exceeded $15 billion, up by 4% from sales in 1999.

Trade in refined bullion comprised 82.5% of U.S. gold imports and 80% of exports; net exports of bullion rose to 256,000 kilograms (kg), up by more than 7% from that of 1999. As shown in tables 4 and 6, Canada provided about 60% of the bullion imported, and Switzerland was the destination for more than 60% of the bullion exported.

The dollar price for gold was volatile in 2000, but prices by yearend were only slightly lower than gold prices at the beginning of the year. Engelhard Corp.'s daily price of gold ranged from a low of nearly $265 per troy ounce[1] on October 27 to a high of about $314 on February 7. The average for the year was, to the nearest dollar, $280. The previous year's prices ranged from about $254 to $327 and averaged $280.

By the third quarter, 12-month London gold lease rates

[1]Elsewhere in this report, ounce by itself refers to troy ounce; 1 kilogram is equivalent to 32.1507 troy ounces.

Gold in the 20th Century

In 1900, the United States led the world in gold production with an output of 119 kilograms of gold, accounting for about 31% of total world production, followed by Australia, Canada, and Russia. A hundred years ago, no gold was produced in South Africa, which is the largest producer of gold today. Colorado was the largest gold-producing State in the United States, providing about 36% of total U.S. gold output. Nevada, which is the leading domestic gold-producing State today, produced only 3% of the total U.S. output in 1900, but would benefit greatly from cyanide-heap leach technology to extract gold from its low-grade gold ores in the late 1960s. The major uses of gold in the early 1900s were for jewelry and monetary investments. At the opening of the 20th century, the official price of gold was $20.67 per troy ounce and Congress passed the Gold Standard Act of 1900, which confirmed the gold dollar as the standard unit of monetary value, with the value of $1 set at 25.8 grains of 900 fine gold. During the First and Second World Wars, the international gold standard was suspended by the combatant but restored following cessation of hostilities. During the Great Depression, exports of gold except under Government license were prohibited, and all gold and gold certificates were recalled from general circulation. In 1934, silver was brought back as a standard unit of monetary value, and the gold content of the gold dollar was reduced to 13.7 grains of 900 fine gold.

In 2000, the United States was the second largest gold-producing country with an output of about 353 kilograms of gold accounting for about 14% of the total world output. South Africa ranked first and Australia, China, and Canada ranked third, fourth, and fifth respectively, in global gold output. Nevada produced three-fourths of U.S. gold, while Colorado produced less than 3% of the total domestic output. Over 85% of today's domestic gold is used for jewelry and arts with most of the remainder used as low-resistance electrical conductors. The price of gold in 2000 averaged $280 per troy ounce, which is about 14 times greater than the price of gold in 1900.

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dropped from about 1.6% in January to 1.2% in October and remained the same through December. Short-term lease rates decreased from historic lows of 0.5% in January to less than 0.3% in August before rising to 0.7% in December (CRU International Ltd., 2001).

Total world mine production of gold was about the same as the record level reached in 1999. Despite a sixth successive decline in annual output, South Africa remained the largest producer of more than 80 gold-mining nations, followed by the United States, Australia, China, and Canada. Identified world gold resources at yearend 1999 were estimated to be 100 million kilograms (Mkg), of which 15% to 20% were byproduct resources; the world reserve base was estimated to be 73 Mkg, and reserves, 48 Mkg (R.P. Ashley, U.S. Geological Survey, oral commun., 2000). [This report uses the resource and reserve terminology of the U.S. Geological Survey (USGS), which is republished annually in USGS Mineral Commodity Summaries (U.S. Bureau of Mines and U.S. Geological Survey, 1980).] South Africa had about 50% of the resources, 50% of the reserve base, and 38% of the reserves. The United States had about 9% of world resources, 8% of the reserve base, and 12% of the reserves.

About 15% of all gold mined is estimated to have been used in dissipative industrial uses, or is either unaccounted for or unrecoverable (Thomas and Boyle, 1986, p. 6). Therefore, of an estimated 140 Mkg of gold mined in historical times through 2000, 119 Mkg of gold remain, with about 33 Mkg held by central banks as official stocks and about 78 Mkg held privately as bullion, coin, and jewelry.

The USGS has issued a report on undiscovered gold, silver, copper, lead, and zinc deposits in the United States (U.S. Geological Survey, 2000). In the report, the amount of gold in undiscovered U.S. mineral deposits is estimated to range between greater than 13 Mkg (90% probability) and greater than 22 Mkg (10% probability). The mean value of gold in the undiscovered deposits is 18 Mkg with nearly one-quarter of the gold estimated to be contained in undiscovered porphyry copper deposits. Other major gold deposit types considered in the report were hot spring gold, epithermal vein, plutonic porphyry gold, sediment-hosted gold, Au-Ag-Te veins, and low-sulfide gold-quartz vein deposits. Total discovered gold resources in the United States were estimated to be 27 Mkg; identified U.S. gold resources were estimated to be 15 Mkg and all U.S. gold production was 12 Mkg.

Production

Domestic mine production data for gold were derived by the USGS from two separate voluntary surveys of U.S. operations—one for monthly production of copper, gold, lead, silver, and zinc from lode mines and the other for the same types of data from companies that responded annually.

Of the 77 lode gold producers in operation to which a survey request was sent, 75 responded. Thirteen of the 75 responses reported that their mines were closed and another 6 remained on care-and-maintenance status by the end of 2000. The individual company production and performance data in table 3 and cited elsewhere in this report were obtained from published sources, such as company annual reports.

Of the total domestic gold produced during 2000, about 93% was extracted from gold ore, and the remaining 7% was derived from other precious-metal ores, base-metal ores, and placer deposits. By comparison, similar data assembled for 1980 indicated a 63% to 37% ratio. In both years, the contribution from placer mines amounted to less than 2% of the total gold produced.

Alaska.—The State's Division of Geology and Geophysical Surveys reported that gold output decreased to 15,600 kg (501,000 ounces) worth $140 million in 2000 from an estimated 16,100 kg (518,000 ounces) worth $144 million in 1999, or an approximate decrease in production of 3% and a decrease in associated value of about 3% (Szumigala and Swainbank, 2001). Placer production dropped to 1,300 kg (41,000 ounces) from 1,700 kg (56,000 ounces) of gold.

The underground Fort Knox gold mine near Fairbanks began to produce gold in 1997. Kinross Gold Corp. reported that the mine produced about 11,300 kg (363,000 ounces) of gold in 2000, making it the country's ninth largest gold producer (Kinross Gold Corp., 2001, p. 24).

The Greens Creek Mine on Admiralty Island, off Juneau, completed its fourth year at full production levels. Ore from the underground trackless mine was milled at the mine site. The mill produced gold and silver doré, lead, zinc, and bulk concentrates. Hecla Mining Co. reported (2001, p. 7) that the mine produced 2,600 kg (83,700 ounces) of gold. Greens Creek was a joint venture between Kennecott Greens Creek Mining Co. (70.3%) and Hecla Mining (29.7%).

USMX Inc.'s Illinois Creek gold mine in west-central Alaska was placed on care and maintenance, but continued to produce gold as the existing heaps were rinsed (Szumigala and Swainbank, 2001).

Continued drilling at the Pogo joint venture between Teck Corp. and Sumitomo Metal Mining America Inc. defined new gold ore zones in the eastern interior region (Wilburn, 2001, p. 49).

California.—Gold production in California remained about the same as that of 1999, as shown in table 2. California's largest gold mine, Newmont Gold Co.'s Mesquite Mine, near Brawley, yielded more than 4,100 kg (130,000 ounces) of gold from oxide and sulfide ores that were mined by open pit methods (Newmont Gold Co., 2001, p. 53).

In eastern Imperial County, Glamis Gold Ltd. continued to produce gold by using heap-leaching methods at its Picacho Mine and continued exploration at its nearby Imperial project. Picacho produced about 45 kg (1,400 ounces). In 1997, after 16 years of gold production, reserves were exhausted, and mining ceased. Gold recovery from the last ore heap was expected to take another year, after which reclamation will begin. Glamis Gold, through its wholly owned Glamis Rand Mining Co., also produced 3,100 kg (100,000 ounces) of gold at its Rand Mine near Randsburg. Almost all mining at the Rand Mine was carried out at the Yellow Aster Pit (Glamis Gold Ltd., 2001, p. 2).

Near the Nevada-California State line, in San Bernardino County, the Castle Mountain Mine produced an estimated 3,700 kg (119,000 ounces) of gold (Viceroy Resource Corp., 2001, p. 2). Castle Mountain was a joint venture between Viceroy Resource Corp. (75%) and MK Gold Co. (25%).

Colorado.—Gold production in the State was 7% higher with a significant increase in production from the Nation's 11th largest gold mine, the Cresson Mine, in the Cripple Creek District of Teller County. AngloGold Ltd. reported (2001, p.

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20) that this open pit mining operation produced 7,700 kg (248,000 ounces) of gold in 2000.

Idaho.—Meridian Gold Inc.'s closure of its Beartrack Mine near Salmon leaves Idaho with no active gold mines. Beartrack produced more than 2,250 kg (73,000 ounces) of gold in 2000 about 45% less than in 1999. Leaching of crushed ore is expected to continue to produce gold over the next several years on a declining basis (Meridian Gold Inc., 2001).

Montana.—Exploration for gold was continued at an extremely low level, funded by a few venture capital dollars. No major mining companies were known to be involved. Low gold prices during the year and market limitations targeted interest toward gold with investment potential, such as free-milling gold and gold placers (McCulloch, 2001, p. 82).

Placer Dome Inc.'s wholly owned Golden Sunlight Mine near Whitehall was Montana's largest gold-producing mine with 6,600 kg (212,300 ounces) of gold in 2000, about 47% more than in 1999 (Placer Dome Inc., 2001, p. 10).

Nevada.—Nevada maintained its longstanding position as the Nation's dominant gold-producing State. Of the Nation's top 30 gold-producing mines, 15 were in the Silver State. Primary gold production increased to 268,000 kg (8.6 million ounces).

Newmont Gold, the largest gold mining company in North America, produced 94,000 kg (3.0 million ounces) of gold from 9 open pit operations, 4 underground mines, and 17 processing facilities in Elko, Eureka, Humboldt, and Pershing Counties. Newmont Gold marked 35 years of production on the Carlin Trend, which it discovered in the mid-1960s. Mining of the high-grade Deep Post pit deposit concluded at the end of 2000, while gold production from stockpiles will continue into early 2001. With reserves of 93,000 kg (3.0 million ounces) of gold, Deep Post consists of both a surface zone, currently being mined within the Betze-Post Pit, and a deeper zone, which was nearly completed as an underground mine, with gold production beginning the first quarter of 2001. Barrick Gold Corp. completed an asset swap with Newmont in May 1999 that provided access to the Deep Post underground deposit zone through a decline at the bottom of the Betze-Post Pit. The asset swap also provided the opportunity to begin a mile-long exploration drift from the Deep Star Mine to the Deep Post Deposit, called the Gold Margin Corridor. Carlin operation's largest open pit mine, Gold Quarry, was mined out in the spring of 2000. In August 2000, mining also ended at the Rosebud underground mine. Exploration drilling near existing gold mines have located an additional 75,000 kg (2.4 million ounces) of gold reserves (Newmont Gold Co., 2001, p. 7).

Barrick Gold Corp. was the Nation's second largest gold mining company in 2000 and reportedly recovered 51,200 kg (1.6 million ounces) of gold at its Betze-Post Mine/Goldstrike in Eureka County. In nearby Elko County, Barrick continued the development of its Meikle Mine/Goldstrike, an underground operation that produced 25,100 kg (806,000 ounces) of gold; it was the Nation's largest underground gold mine. The mine had an underground cooling system to keep temperatures around 80 F even though the temperature of the surrounding rock can be 140 F (Gold News, 1998). These Barrick operations on the Carlin Trend were developed within a 2,800-hectare landholding known as the Goldstrike Property (Barrick Gold Corp., 2001, p. 5).

Northwest of Elko, AngloGold Ltd. and Meridian Gold Inc. produced about 10,700 kg (344,000 ounces) of gold at their Jerritt Canyon Mine, the Nation's 10th largest gold mine (AngloGold Ltd., 2001, p. 20). Other gold mines in Humboldt County included the Hycroft (formerly the Crowfoot/Lewis) and the Marigold Mines.

South of and parallel to the Carlin Trend, the Battle Mountain/Eureka Trend runs from southeastern Humboldt County southeast through Lander and Eureka Counties. Gold mining operations along this trend in Lander County include the Battle Mountain Complex, which was placed on care and maintenance on January 1, 2000 (Battle Mountain Gold Co., 2000, p. 7); the McCoy/Cove gold and silver mine, which produced 5,100 kg (163,000 ounces) (Echo Bay Mines Ltd., 2001, p. 9); and the country's fourth largest gold mine, the Cortez Mine, owned by Placer Dome (60%) and Kennecott Minerals Co. (40%), which produced 31,400 kg (1.0 million ounces) (Placer Dome Inc., 2001, p. 9).

At Round Mountain, about 95 kilometers (km) north of Tonopah, the Round Mountain Gold Corp. mine of Echo Bay Mines Ltd. produced about 19,800 kg (638,000 ounces) of gold during the year (Echo Bay Mines Ltd., 2001, p. 9). The property is the sixth largest U.S. gold mine.

Battle Mountain Gold Co. continued its exploration project by extending the Phoenix Zone at the Battle Mountain Complex, thereby adding about 31,000 kg (1 million ounces) of gold to its reserve base. In addition, Dynatec Corp. continued to develop the Rossi-Storm Deposit at the Ken Snyder Mine, which poured its first gold on December 9, 1998. Ken Snyder's second full year of commercial production was 5,300 kg (171,000 ounces) of gold making it the country's 13th largest gold mine in 2000 (Franco-Nevada Mining Corp. Ltd., 2001, p. 2).

Exploration continued to decline. Activity was concentrated along the major "trends," Battle Mountain, Carlin, Getchell, and Midas. Several companies pursued high-grade vein targets, such as feeder-vein systems beneath the former Hog Ranch open pit mine in Washoe County and the Hollister open pit mine in Elko County (Tingley and LaPointe, 2001, p. 82).

South Dakota.—Gold production decreased by more than 17% compared with that of 1999. Homestake Mining Co's 124-year-old Homestake Mine at Lead will be shut down by the end of 2001. Homestake plans to produce about 7,500 kg (240,000 ounces) of additional gold before closure, and expects to spend over $66 million over 8 years on final reclamation and remediation (American Metal Market, 2000g). The Homestake Mine was again the largest gold-producing mine in South Dakota and the 14th largest gold-producing mine in the country. During the year, the mine, a nearly 2.5-km-deep operation with associated surface mining, yielded about 5,300 kg (171,000 ounces) of gold (Homestake Mining Co., 2001, p. 4).

Goldcorp Inc. operated an open pit gold mine near Lead, the Wharf Mine, which produced about 2,900 kg (94,000 ounces) of gold (Goldcorp Inc., 2001, p. 5).

Utah.—Rio Tinto Ltd.'s Bingham Canyon Mine, which was operated by Kennecott Utah Copper Corp., produced about 16,500 kg (529,000 ounces) of gold as a byproduct of its copper mining operations near Salt Lake City. Long ranked as one of the Nation's principal gold-producing mines, Bingham Canyon was the seventh largest gold producer in 2000. Kennecott also operated the nearby Barney's Canyon Mine, an open pit and heap-leaching operation that produced 4,800 kg (153,000 ounces) of gold (Rio Tinto Ltd., 2001, p. 3).

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Washington.—Echo Bay Mines's Kettle River underground mine, in the northeastern part of the State, produced 2,900 kg (94,000 ounces) of gold in its 10th year of production (Echo Bay Mines Ltd., 2001, p. 9).

The Crown Jewel project, with projected annual production of 5,400 kg (175,000 ounces) of gold, received an unfavorable ruling on a water-quality permit. The ruling, made by Washington State's Pollution Control Hearings Board, delayed the project's startup date (American Metal Market, 2000d).

World Review

World gold mine production was about the same as in 1999. Increased production from mines in Russia and the United States was enough to help offset a continuing decline in gold output from South Africa. According to its annual review of world gold supply and demand, Gold Fields Mineral Services Ltd. calculated that the total global supply of gold in 2000 was 3.95 Mkg (123 million ounces) compared with the previous year's total supply of 4.15 Mkg (129 million ounces) (Klapwijk and others, 2001, p. 7). Gold Fields Mineral Services also reported level mine production; increases in official sector sales (1.5%); no net producer hedging; and a implied net disinvestment of 291,000 kg (9 million ounces), which was sales of bars and coins by private investors. Old gold scrap levels hardly changed in 2000 (Klapwijk and others, 2001, p. 7).

On the demand side, Gold Fields Mineral Services reported only 5,000 kg (155,000 ounces) less that its 1999 level. Jewelry fabrication increased by 26,000 kg (810,000 ounces) as strong growth in the Middle East outweighed weakness in the Indian subcontinent and Europe. Bar hoarding fell by 18% largely as a result of lower Japanese demand. Coin fabrication collapsed to 46,000 kg (1.4 million ounces), but the amount of gold used in electronics increased by 15% (Klapwijk and others, 2001, p. 10).

With regard to gold exploration, the Metals Economics Group, Halifax, Nova Scotia, Canada, determined from its annual survey of worldwide exploration budgets for 656 companies (diGesu and others, 2000a) that $1.09 billion (46%) of the 2000 world exploration budget total for nonferrous metals was directed to gold, with 428 companies reporting active gold programs. The expenditures for gold were $238 million less than the $1.33 billion (52% of the total) reported for gold exploration in 1999. As in the preceding 6 years, Latin America received the highest expenditure for gold—$662.9 million (28%) of the reported 2000 world total exploration dollars (diGesu and others, 2000b).

Australia.—Australian gold mine production dropped by about 2% from 1999. However, Australia retained its position as the world's third largest gold-producing nation. Of the 296,400 kg (9.2 million ounces) of gold mined in 2000, Western Australia, Queensland, and Northern Territory accounted for about 70%, 12%, and 8%, respectively (Australian Bureau of Agricultural and Resource Economics, 2001, p. 15); Western Australia's production was derived principally from mining operations near Kalgoorlie. Other Australian gold-producing States were, in descending order of output, New South Wales, Victoria, Tasmania, and South Australia.

Cost at the Granny Smith Mine, traditionally one of the lowest producers, doubled. The higher costs were partially a result of lower gold production as waste rock was mined to gain access to an ore zone. In addition, operational difficulties were experienced owing to harsh weather during the first quarter (Klapwijk and others, 2001, p. 45).

The Australian Bureau of Statistics reported that expenditures for mineral exploration in Australia increased during the second quarter of 2000. The 4% increase in spending marked a reversal in the decline of exploration expenditures in Australia since 1997. Spending for gold exploration, which accounted for the largest share of total spending, rose by more than $20 million in the second quarter of 2000 (American Metal Market, 2000a).

Medals for the Sydney Olympics were made from donated newly mined gold and silver, plus old Australian coins that were out of circulation. Each gold metal was made of pure silver with a minimum of 6 grams of gold for plating. During the Olympic Games, 650 gold metals were awarded (American Metal Market, 2000b).

Brazil.—During 2000, gold production declined 1% to about the 52-metric-ton (1.7-million-ounce) level. Output from the informal, noncorporate mining sector, the garimpeiros, was estimated to have dropped to as low as 12,000 kg (370,000 ounces) of gold. Low gold prices, higher fuel prices, stricter environmental controls, and restriction of mining activities in native Indian reserves encouraged garimpeiros to find alternative and more formal employment. Most of the formal mining sector, however, performed well, maintaining about 40,000 kg (1.3 million ounces) of gold production by reducing costs (Klapwijk and others, 2001, p. 37).

Canada.—Canada dropped to fifth position in the ranking of world gold producers, as its output declined by 2% to 154,000 kg. Gold was produced at about 33 lode gold mines, the same as that of 1999. During the year, no gold mines began operation, six gold mines reopened, and six gold mines shutdown or suspended operations. Canada's principal gold-producing Provinces were Ontario (47%), Quebec (22%), British Columbia (17%), and Manitoba (5%). Gold was also produced in Alberta, New Brunswick, Newfoundland, Nunavut, Saskatchewan, the Northwest Territories, and Yukon Territory. The reopening of the Red Lake Mine in northwestern Ontario in August, after 4 years of shutdown due to a labor dispute, was the highlight of the year for gold mining in Canada. Highly successful exploration work, which resulted in the discovery of the nonrefractory High Grade Zone, allowed the mine to be redeveloped into an exceptionally high-grade and low-cost gold mine. The mine is currently the lowest cost gold mine in Canada (Michel Miron, Natural Resources Canada, written commun., 2001).

Chile.—Gold output in Chile increased 19% to 54,000 kg (1.7 million ounces) despite a number of mine closures. Closures included the high-cost Andacollo Mine, which suspended operations in September, and the El Tambo Mine where operations ceased in June due to ore depletion. The new El Peñon had a strong performance, adding just under 10,000 kg (3.0 million ounces) to Chile's gold output in 2000 (Klapwijk and others, 2001, p. 37).

China.—The Chinese produced 180,000 kg of gold in 2000, up 4% from the 173,000 kg of gold produced in 1999 (Platts Metals Week, 2001).

The Chinese Government released an outline of how China is restructuring its gold market in a series of economic reforms to comply with standards set by the World Trade Organization for membership. China is also expected to establish a national gold

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exchange in 2001, which will trade only spot gold. China produces 180,000 kg of gold from 1,200 mines, and its central bank holds 395,000 kg of gold (American Metal Market, 2000c).

India.—The Delhi Stock Exchange offered online trading in gold bullion early in November and thereby initiated the first stock exchange in India for bullion trading. Almost 29 Mkg of gold, valued at $300 billion, are held in India. The Government holds only about 400,000 kg of gold, with the remainder in private hands. In addition, India imports over 800,000 kg of gold annually to satisfy its demand for jewelry (American Metal Market, 2000e).

Indonesia.—Gold output was estimated to have dropped by 2% in 2000 to 125,000 kg. The Grasberg Mine, which produced 96,000 kg of gold, generated as a byproduct 77% of the country's gold output. Also, the Minahasa and Kelian Mines declined in gold output owing to industrial action and community protests through road blocks. Losses were more than offset by extra gold output from two new gold mining operations: The Gosowong Mine produced more than 7,000 kg of gold in its first full year of operation. In addition, the Batu Hijau copper-gold mine shipped its first concentrate at the end of 1999 and contributed almost 10,000 kg to Indonesian gold output in 2000 (Klapwijk and others, 2001, p. 39).

Mexico.—Gold production increased by 11% to almost 26,000 kg in 2000 (Klapwijk and others, 2001, p. 37).

The International Monetary Fund (IMF) has completed its planned sales of over 400,000 kg (13 million ounces) of gold by reevaluating the gold without depressing the gold market. Seven off-market transactions were made with the borrowing countries, Brazil and Mexico, selling the gold, buying it back, and raising cash by reevaluating the gold. The off-market transactions were part of an agreement to fund the IMF's share of the "Highly Indebted Poor Countries" (HIPC) initiative. IMF sold its gold to Brazil and Mexico and accepted it back immediately from Brazil and Mexico for payment of an obligation due that same day. IMF takes advantage of the difference between the value of gold on its books and the much higher market price. The cash is then invested and the interest is used to support the HIPC initiative (American Metal Market, 2000f).

Papua New Guinea.—Gold production in Papua New Guinea rose over 21% to 74,000 kg. Porgera Mine showed a 20% increase in gold production owing to higher grades and improved recovery at the plant. Record gold output of 16,000 kg was reported at the Ok Tedi Mine, however, it is still embroiled in a protracted court battle with landowners over damage caused by waste in rivers around the mine (Klapwijk and others, 2001, p. 40).

Peru.—For the fifth consecutive year, gold production in Peru exceeded that in Brazil, making it the largest gold producer in Latin America at 133,000 kg of gold, which was 3% more than that of 1999. Gains at the Yanacocha and Orcopampa Mines were enough to offset the losses from the Pierina Mine where gold output declined 2%, as lower grade ore was processed. Further losses of 25% were expected and reported at the Sipan Mine. Production is expected to rise even further at the large-scale, low-cost, open pit, heap-leach Yanacocha Mine in northern Peru, when La Quinua (one of the five deposits that constitute the Yanacocha Mine) is brought into production in 2001 (Klapwijk and others, 2001, p. 36).

Russia.—Production in Russia grew by 11%, to 140,000 kg of gold, moving Russia to the sixth position among the top gold producing countries. Two years of strong growth in gold production indicate that gold reserves are available to be mined should Russian owners receive adequate financial backing. Liberalization in the gold industry, which started a few years ago and accelerated after the economic crisis of 1998, allowed many commercial banks to obtain licenses for trading and exporting gold. The proliferation of these banks has provided more than sufficient funding to the gold industry, which buys between 70% and 80% of the gold from the mines. Much of the buying is completed through prepurchasing schemes entered into before the gold is produced. Most of the gold is exported with a 5% export duty on precious metals ores and concentrate imposed by the Central Bank (Klapwijk and others, 2001, p. 40).

South Africa.—Gold production in South Africa, the world's largest gold-producing nation, declined for the seventh consecutive year, to 431,000 kg of gold, 5% less than that of 1999, and left gold production at its lowest level in 46 years. South Africa has not had a year-on-year increase in gold output since 1993, and consequently with the increase in gold production in Australia and North America, its share fell from 30% of the world's gold output in 1993, to roughly 17% in 2000. The successive declines can, in part, be explained by operational difficulties related to the maturity of the industry and the nature of the ore deposits: narrow veins in hard rock being mined at deep levels. In 2000, the number of working shifts were reduced, which also affected gold production (Klapwijk and others, 2001, p. 33).

The tonnage and grade of ore milled during 2000 by the mines comprising the membership of the Chamber of Mines of South Africa amounted to almost 84 billion kilograms at a grade of 4.51 grams per ton of gold ore; this compares with a higher total tonnage of 87 billion kilograms at a higher grade of 4.62 grams per ton that was milled by Chamber members in 1999.

Of the top 15 gold-producing companies in the world in 2000, 4 were South African. AngloGold Ltd., listed on the Australian Stock Exchange in November 1999, remained the leading gold-producing company in the world. Gold Fields Ltd. was third in the world. The other two companies were Harmony Gold Mining Co. Ltd. (8th) and Durban Roodepoort Deep Ltd. (12th). Durban Roodepoort Deep was listed on the Australian Stock Exchange in March 1999 (Klapwijk and others, 2001, p. 31).

Uzbekistan.—Gold production in Uzbekistan remained constant at 85,000 kg. Gold output at the Zarafshan-Newmont Gold's joint venture, which processes high-grade tailings from the state-owned Muruntau Mine at Zarafshan, dropped by 8% primarily due to changes in production levels. In addition, Navoi Mining and Minerals, operators of the Muruntau Mine in the Kyzylkum desert, reported throughput and fine gold recovery increased. Navoi announced plans to start building a biooxidation plant at its Uchkuduk site, which could see gold output increase further in the future (Klapwijk and others, 2001, p. 41).

Outlook

World gold producers are expected to reduce capital spending during the next 2 or 3 years. Small-to-medium-sized companies will be absorbed by the larger gold mining companies, and the

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largest companies will merge as a consolidation phase takes place in the gold mining industry. This trend of consolidation to maintain gold reserves is expected to continue; thus, forecasts of a future gold industry comprised of less than 10 major companies cannot be easily dismissed. Moreover, larger companies that produce as much as 300,000 kilograms per year of gold could materialize in the next 2 to 3 years.

Capital spending reductions will occur; this means less gold exploration and suggests that new pipeline projects will not be sufficient to replace old ones. The U.S. gold industry already has been closing its gold mines, 10 in 1999 and 12 more in 2000. It is not only the low price of gold that drives spending down; it is also due to lack of investor interest because too many gold companies are generating poor returns.

References Cited

American Metal Market, 2000a, Australian mineral exploration rebounds slightly but still lags: American Metal Market, v. 108, no. 182, September 20, p. 4.

———2000b, Australians add local color to medals for Olympic Games: American Metal Market, v. 108, no. 166, August 28 p. 15.

———2000c, Barclays releases outline of China's gold liberalization: American Metal Market, v. 108, no. 182, September 20, p. 4.

———2000d, Crown Jewel mine stalled: American Metal Market, v. 108, no. 15, January 25, p. 6.

———2000e, Delhi Stock Exchange ready to debut online gold trading: American Metal Market, v. 108, no. 182, September 20, p. 14.

———2000f, IMF completes gold transactions for debt relief: American Metal Market, v. 108, no. 69, April 11, p. 7.

———2000g, Low grades, high costs force mine closing: American Metal Market, v. 108, no. 178, September 14, p. 6.

AngloGold Ltd., 2001, Report for the quarter and year ended 31 December 2000: Republic of South Africa, AngloGold Ltd. news release, January 30, 60 p.

Australian Bureau of Agricultural and Resource Economics, 2001, Australian mineral statistics, fourth quarter 2000: Canberra, Australian Bureau of Agricultural and Resource Economics, 32 p.

Barrick Gold Corp., 2001, Barrick achieves record 2000 production and cash flow record earnings before US$1.1 billion provision—Reserves remain intact at US$300 gold: Toronto, Canada, Barrick Gold Corp. press release, February 1, 19 p.

Battle Mountain Gold Co., 2000, Form 10-K: Washington, DC, U.S. Securities and Exchange Commission, 97 p.

CRU International Ltd., 2001, Precious metals market outlook: London, CRU International Ltd., Q2, 94 p.

diGesu, Dominique, Bearmish, Marilyn, Angelucci, Josee, Fox, Debbie, Haynes, Shelley, Hopkinson, Lori, Lowery, Jim, Slaunwhite, Janice, and Selva, Sandra, 2000a, Overview of worldwide exploration budgets (part I): Halifax, Nova Scotia, Canada, Metals Economics Group Strategic Report, v. 13, no. 5, September-October, p. 1-5.

——— 2000b, Overview of worldwide exploration budgets (part II): Halifax, Nova Scotia, Canada, Metals Economics Group Strategic Report, v. 13, no. 6, November-December, p. 12-19.

Echo Bay Mines Ltd., 2001, Echo Bay Mines announces fourth quarter and full year 2000 results: Englewood, CO, Echo Bay Mines Ltd. press release, February 15, 19 p.

Franco-Nevada Mining Corp. Ltd., 2001, Franco-Nevada reports third quarter results and is on track for a record year: Toronto, Canada, Franco-Nevada Mining Corp. Ltd. news release, January 31, 7 p.

Glamis Gold Ltd., 2001, Glamis Gold achieves record gold production and reports improved outlook for 2001: Reno, NV, Glamis Gold Ltd. news release, February 20, 4 p.

Gold News, 1998, Gold snapshot—Underground mines are growing trend: Gold News, November-December, p. 2.

Goldcorp Inc., 2001, Goldcorp annual report 2000: Toronto, Canada, Goldcorp Inc., 28 p.

Hecla Mining Co., 2001, Hecla releases 4th quarter and year-end results, produces nearly 8 million ounces of silver: Coeur D'Alene, ID, Hecla Mining Co. press release, March 6, 8 p.

Homestake Mining Co., 2001, Homestake reports Q4 earnings of $0.02 per share, all-time record quarterly and annual gold production, lowest cash costs in 23 years: Walnut Creek, CA, Homestake Mining Co. news release, February 6, 25 p.

Kinross Gold Corp., 2001, Kinross annual report 2000: Toronto, Canada, Kinross Gold Corp., 60 p.

Klapwijk, Philip, le Roux, Hester, Walker, Paul, Newman, Philip, and Alway, Bruce, 2001, Gold 2001: Gold Fields Mineral Services Ltd., 113 p.

McCulloch, R.B., 2001, Montana: Mining Engineering, v. 53, no. 5, May, p. 80-82.

Meridian Gold Inc., 2001, Meridian Gold reports record profits in the fourth quarter and full year 2000: Reno, NV, Meridian Gold Inc. press release, February 22, p. 2.

Newmont Gold Co., 2001, Newmont Gold Company annual report 2000: Denver, CO, Newmont Gold Co., 58 p.

Placer Dome Inc., 2001, Placer Dome reports record cash flow and mine operating earnings: Vancouver, B.C., Canada, Placer Dome Inc. press release, February 15, 19 p.

Platts Metals Week, 2001, China's gold demand could rise: Platts Metals Week, v. 72, no. 9, February 26, p. 4.

Rio Tinto Ltd., 2001, Rio Tinto quarterly production report for the quarter ending 31 December 2000: London, England, Rio Tinto Ltd. media release, January 24, 24 p.

Szumigala, D.J., and Swainbank, R.C., 2001, Alaska's mineral industry 2000: Alaska Division of Geology and Geophysics Surveys Information Circular 47, March, 14 p.

Thomas, P.R., and Boyle, E.H., Jr., 1986, Gold availability appraisal: U.S. Bureau of Mines Information Circular 9070, 87 p.

Tingley, J.V., and LaPointe, D.D., 2001, Nevada: Mining Engineering, v. 53, no. 5, May, p. 82-86.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

U.S. Geological Survey, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

Viceroy Resource Corp., 2001, Viceroy year-end 2000 results & review: Vancouver, Canada, Viceroy Resource Corp. press release, March 9, p. 2.

Wilburn, D.R., 2001, Exploration: Mining Engineering, v. 53, no. 5, May, p. 41-51.

World Gold Council, 2001, 2000 gold jewelry sales exceed $15 billion record; sales continue 10 year growth trend: New York, NY, World Gold Council press release, July 16, 2 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Contributions to the Gold Metallogeny of Northern Nevada: (CD-ROM), U.S. Geological Survey Open-File Report 98-338, 1999.

Geologic and Grade-Tonnage Information on Tertiary Epithermal Precious- and Base-Metal Vein Districts Associated With Volcanic Rocks, Bulletin 1666, 1986.

Geologic Characteristics of Sediment- and Volcanic-Hosted Disseminated Gold Deposits—Search for an Occurrence Model, Bulletin 1646, 1985.

Geology and Resources of Gold in the United States, Bulletin 1857, 1998.

Gold. Ch. in Mineral Commodity Summaries, annual.

Gold. Ch. in Minerals Yearbook, annual.

Gold. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Precious Metals. Mineral Industry Surveys, monthly.

Principal Gold-Producing Districts of the United States, Professional Paper 610, 1968.

Other

American Metal Market, daily.

Canadian Mines Handbook 1997-98.

Digitized by Google

Engineering and Mining Journal, monthly.
Gold. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Jewelers' Circular-Keystone, monthly.
Mining Journal, biweekly.
The Mining Record, weekly.
The Northern Miner, weekly.
Platts Metals Week, weekly.
Randol Mining Directory 1999.
World Gold—A Minerals Availability Appraisal, U.S. Bureau of Mines Special Publication SP 24-94, 1994.

TABLE 1
SALIENT GOLD STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Mine production	kilograms	326,000	362,000	366,000	341,000	353,000
Value	thousands	$4,090,000	$3,870,000	$3,480,000	$3,070,000	$3,180,000
Gold recovered by cyanidation:						
Extracted in vats, tanks, closed containers 2/	kilograms	170,000	201,000	238,000	196,000	90,000
Leached in open heaps or dumps 3/	do.	124,000	132,000	103,000	131,000	193,000
Refinery production:						
Concentrates and doré	do.	NA	270,000	277,000	265,000	197,000
Recycled materials (new and old scrap)	do.	NA	100,000	163,000	143,000	81,600
Exports, refined	do.	406,000	391,000	430,000	435,000	440,000
Imports for consumption, refined	do.	143,000	194,000	257,000	196,000	184,000
Net deliveries from foreign stocks in Federal Reserve Bank of New York	do.	373,000	143,000	310,000	303,000 r/	356,000
Stocks, December 31:						
Industry 4/	do.	NA	17,300	16,600	14,700	9,300
Commodity Exchange (Comex) 5/	do.	20,700	15,200	25,200	37,900	52,900
Department of the Treasury	metric tons	8,140	8,140	8,130	8,170	8,140
Volume of U.S. Gold Futures Trading 6/	do.	14,300	29,700	28,600	29,800	20,600
Department of the Treasury: 7/						
American Eagle gold coin	kilograms	10,700	20,000	49,200	78,200	13,900
Other numismatic gold coins	do.	1,190	500	86	430	330
Consumption in industry and the arts	do.	NA	137,000	219,000	245,000	183,000
Apparent demand, refined 8/	do.	NA	265,000	667,000	283,000	380,000
Price, average per troy ounce 9/		389	332	295	280	280
Employment, mine and mill only 10/		16,900	16,300	13,400	10,300	10,400
World:						
Production, mine	kilograms	2,290,000 r/	2,450,000	2,510,000 r/	2,550,000 r/	2,550,000 e/
Official bullion reserves 11/	metric tons	34,400	34,000	33,600	33,500 r/	33,000

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than three significant digits, except prices.

2/ May include small quantities recovered by gravity methods.

3/ May include tailings, waste-ore dumps, and previously mined ore at some inactive mines.

4/ Unfabricated refined gold held by refiners, fabricators, dealers, and the U.S. Department of Defense.

5/ Commodity Exchange (Comex) Division of the New York Mercantile Exchange.

6/ Comex only.

7/ Fiscal year bullion disbursements to U.S. Mint coin programs. Fiscal year begins October 1, of year prior to year indicated.

8/ Defined as refinery production from primary materials plus refinery production from old scrap plus net bullion flow to market from foreign stocks at the New York Federal Reserve Bank plus net imports of bullion. Assumed to include gold held for investment purposes. Excludes gold contained in fabricated items, imported coins, and official monetary gold.

9/ Engelhard Corp. industries quotation.

10/ Data from Mine Safety and Health Administration.

11/ Held by central banks, governments, and international monetary organizations. Data from International Monetary Fund.

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TABLE 2
MINE PRODUCTION OF GOLD IN THE UNITED STATES, BY STATE 1/

(Kilograms)

State	1999	2000
Alaska 2/	16,200 r/	15,600
Arizona	786	442
California	17,500	17,200
Idaho	W	W
Montana	7,540 r/	9,310
Nevada	256,000 r/	268,000
South Dakota	10,300 r/	8,230
Washington	3,250	2,930
Other States 3/	29,700 r/	31,700
Total	341,000	353,000

r/ Revised. W Withheld to avoid disclosing company proprietary data, included with "Other States."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Production data collected by the State.
3/ Includes Colorado, New Mexico, South Carolina, Utah, Wisconsin, and States indicated by symbol W.

TABLE 3
LEADING GOLD-PRODUCING MINES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT 1/

Rank	Mine	County and State	Operator	Kilograms
1	Betze-Post/Goldstrike	Eureka, NV	Barrick Gold Corp.	51,200
2	Twin Creeks 2/	Humboldt, NV	Newmont Gold Co.	41,100
3	Carlin operations 2/	Elko, Eureka, NV	do.	37,000
4	Cortez	Lander, NV	Placer Dome Inc.	31,400
5	Meikle/Goldstrike 3/	Elko, NV	Barrick Gold Corp.	25,100
6	Round Mountain	Nye, NV	Round Mountain Gold Corp.	19,800
7	Bingham Canyon 4/	Salt Lake, UT	Kennecott Utah Copper Corp.	16,500
8	Lone Tree 2/	Humboldt, NV	Newmont Gold Company	15,100
9	Fort Knox 5/	Fairbanks, AK	Fairbanks Gold Mining Inc.	11,300
10	Jerritt Canyon	Elko, NV	Independence Mining Co., Inc.	10,700
11	Cresson	Teller, CO	Cripple Creek & Victor Gold Mining Co.	7,700
12	Golden Sunlight	Jefferson, MT	Placer Dome Inc.	6,600
13	Ken Snyder	Elko, NV	Euro-Nevada Mining Co.	6,040
14	Homestake	Lawrence, SD	Homestake Mining Co.	5,320
15	McCoy/Cove	Lander, NV	Echo Bay Mines Ltd.	5,060
16	Barney's Canyon	Salt Lake, UT	Kennecott Barney's Canyon Mining Co.	4,760
17	Bald Mountain	White Pine, NV	Placer Dome Inc.	4,180
18	Mesquite 2/	Imperial, CA	Newmont Gold Co.	4,060
19	Ruby Hill	Eureka, NV	Homestake Mining Co.	3,890
20	Castle Mountain	San Bernardino, CA	Viceroy Resources Corp.	3,690
21	McLaughlin	Napa, Yolo, CA	Homestake Mining Co.	3,350
22	Denton-Rawhide	Mineral, NV	Kennecott Rawhide Mining Co.	3,250
23	Rand	Kern, CA	Glamis Rand Mining Co.	3,110
24	Kettle River	Ferry, WA	Echo Bay Mines Ltd.	2,930
25	Wharf	Lawrence, SD	Wharf Resources, Ltd.	2,920
26	Briggs	Inyo, CA	Canyon Resources Corp.	2,690
27	Greens Creek 6/	Juneau, AK	Kennecott Greens Creek Mining Co.	2,510
28	Rochester	Pershing, NV	Coeur d'Alene Mines Corp.	2,360
29	Beartrack	Lemhi, ID	Meridian Gold Inc.	2,250
(7/)	Florida Canyon	Pershing, NV	Florida Canyon Mining, Inc.	W

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; these mines accounted for more than 96% of the U.S. gold production in 2000.
2/ Mill output.
3/ Previously reported county location was incorrect.
4/ Mine production refers to total quantity of gold produced in concentrates.
5/ Mine production refers to gold equivalent produced.
6/ Updated to reflect locality name change.
7/ Production at Florida Canyon is withheld; mine is among the top 30 gold-producing mines in the United States, but is not shown in rank order to avoid disclosing company propriety data.

Sources: Company annual reports, Securities and Exchange Commission's 10K and 6K reports, and company news releases.

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TABLE 4
U.S. EXPORTS OF GOLD, BY COUNTRY 1/ 2/

Year and country	Ores and concentrates 3/		Doré and precipitates		Refined bullion 4/		Total	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1999	117	$1,180	87,300	$778,000	435,000	$3,880,000	523,000	$4,660,000
2000:								
Armenia	--	--	--	--	284	2,560	284	2,560
Australia	--	--	--	--	10,900	99,100	10,900	99,100
Austria	--	--	--	--	50	470	50	470
Bahamas, The	--	--	--	--	29	221	29	221
Bolivia	--	--	--	--	42	360	42	360
Brazil	9	89	--	--	402	3,430	411	3,520
Canada	--	--	4,550	28,700	4,350	43,800	8,900	72,400
China	2	20	--	--	--	--	2	20
Costa Rica	--	--	--	--	(5/)	3	(5/)	3
France	5	40	--	--	(5/)	5	5	44
Germany	494	6,800	10	65	115	886	620	7,750
Guatemala	--	--	--	--	511	5,000	511	5,000
Hong Kong	(5/)	3	--	--	2,200	19,800	2,200	19,800
Iceland	--	--	--	--	(5/)	4	(5/)	4
India	--	--	18	137	--	--	18	137
Ireland	--	--	3	27	14	70	17	97
Israel	--	--	7	44	8	63	15	107
Italy	--	--	--	--	58	620	58	620
Japan	--	--	134	1,020	425	4,760	559	5,780
Korea, Republic of	1	5	--	--	1,160	9,830	1,160	9,840
Mexico	149	1,590	514	6,820	31,000	295,000	31,700	303,000
Netherlands Antilles	--	--	2	6	2	23	4	29
Pakistan	--	--	--	--	57	512	57	512
Peru	--	--	--	--	6,180	53,200	6,180	53,200
Philippines	7	52	--	--	6	68	13	120
Romania	--	--	--	--	5	39	5	39
Saudi Arabia	--	--	--	--	1,970	17,600	1,970	17,600
Singapore	--	--	8	81	1,080	9,460	1,090	9,540
South Africa	--	--	--	--	1	6	1	6
Spain	--	--	--	--	(5/)	3	(5/)	3
Sweden	--	--	8	37	12	105	20	141
Switzerland	35	342	100,000	887,000	267,000	2,460,000	368,000	3,350,000
Taiwan	--	--	27	178	1,890	17,000	1,920	17,100
Turkey	--	--	--	--	217	1,950	217	1,950
United Arab Emirates	--	--	--	--	3,290	28,500	3,290	28,500
United Kingdom	42	739	--	--	107,000	955,000	107,000	956,000
Venezuela	--	--	--	--	61	595	61	595
Total	745	9,680	106,000	924,000	440,000	4,030,000	547,000	4,970,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Ash and residues data were zero for listed years.
3/ Includes base metal ores, concentrates, and matte destined for refining.
4/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF GOLD, BY COUNTRY 1/

Year and country	Waste and scrap		Metal powder		Gold compounds	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1999	40,000	$302,000	270	$2,800	561,000	$14,100
2000:						
Armenia	7	67	--	--	--	--
Australia	2	15	--	--	867	54
Belgium	1,870	17,100	--	--	--	--
Bermuda	--	--	2	8	--	--
Brazil	--	--	--	--	361	20
British Virgin Islands	--	--	1	6	--	--
Canada	26,500	168,000	56	500	1,100,000	7,700
China	339	3,230	--	--	--	--
Colombia	--	--	3	25	5,510	55
Denmark	--	--	--	--	11,300	54
Dominican Republic	--	--	--	--	1,230	127
France	5	80	4	41	27	8
Germany	1,390	18,300	23	155	14	14
Guatemala	50	458	--	--	--	--
Hong Kong	5	25	3	64	7,780	84
India	--	--	1	19	1	3
Israel	10	237	18	193	216,000	1,560
Italy	2,000	16,000	(2/)	5	16,800	80
Jamaica	1	21	15	146	--	--
Japan	13	174	45	515	521	11
Korea, Republic of	--	--	--	--	16,500	79
Kuwait	--	--	--	--	4,940	24
Lebanon	--	--	2	7	--	--
Mexico	281	2,670	232	2,350	8,460	3,530
Netherlands	--	--	1	19	207	1,120
Netherlands Antilles	(2/)	11	4	34	--	--
Pakistan	4	36	1	9	--	--
Singapore	1	25	1	18	709	460
South Africa	--	--	1	5	1	10
Sweden	982	9,420	5	28	--	--
Switzerland	19	181	2	19	--	--
Taiwan	12	486	(2/)	3	--	--
Thailand	--	--	1	9	--	--
United Arab Emirates	1	19	7	60	--	--
United Kingdom	30,600	464,000	697	6,460	1,960	304
Venezuela	--	--	2	16	--	--
Total	64,100	700,000	1,130	10,700	1,390,000	15,300

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY 1/

Year and country	Ores and concentrates 2/		Doré and precipitates		Refined bullion 3/		Ash and residues		Total	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1999	117	$1,130	24,700	$210,000	196,000	$1,790,000	133	$1,760	221,000	$2,000,000
2000:										
Argentina	--	--	181	1,400	--	--	--	--	181	1,400
Aruba	--	--	--	--	622	6,000	--	--	622	6,000
Australia	38	392	5	35	151	1,330	--	--	194	1,750
Belgium	--	--	--	--	(4/)	3	--	--	(4/)	3
Bolivia	--	--	204	1,720	144	1,200	--	--	348	2,930
Brazil	--	--	135	1,080	40,100	364,000	--	--	40,200	365,000
Canada	27	243	6,090	52,700	110,000	1,020,000	32	586	116,000	1,070,000
Chile	--	--	1,690	18,900	6,000	54,700	13	114	7,710	73,700
Colombia	--	--	1,170	8,340	7,880	62,000	--	--	9,040	70,300
Costa Rica	--	--	139	1,170	--	--	--	--	139	1,170
Dominican Repuiblic	--	--	--	--	238	2,200	--	--	238	2,200
Ecuador	--	--	134	1,180	69	627	--	--	203	1,810
El Salvador	--	--	--	--	2	17	--	--	2	17
Fiji	--	--	--	--	786	9,350	--	--	786	9,350
France	--	--	--	--	683	6,310	--	--	683	6,310
Germany	--	--	--	--	10	38	--	--	10	38
Ghana	--	--	4	45	--	--	--	--	4	45
Guyana	--	--	67	710	4	34	--	--	71	744
Heard and McDonald Islands	--	--	22	112	--	--	--	--	22	112
Honduras	--	--	983	6,520	77	377	--	--	1,060	6,900
Israel	--	--	--	--	100	924	--	--	100	924
Italy	--	--	18	218	1	12	--	--	20	229
Jamaica	--	--	--	--	1	12	--	--	1	12
Mali	--	--	--	--	7	60	--	--	7	60
Mexico	--	--	4,450	37,900	786	7,440	8	91	5,250	45,400
Nicaragua	--	--	730	4,390	399	4,160	6	1,010	1,130	9,550
Norway	--	--	--	--	433	3,830	--	--	433	3,830
Panama	--	--	--	--	368	3,230	--	--	368	3,230
Peru	--	--	11,400	100,000	2,670	23,000	--	--	14,100	123,000
Russia	--	--	10	123	--	--	--	--	10	123
Singapore	--	--	1	7	(4/)	4	--	--	1	10
South Africa	--	--	--	--	2	22	--	--	2	22
Spain	--	--	--	--	1	7	--	--	1	7
Switzerland	--	--	--	--	1,150	10,300	--	--	1,150	10,300
United Arab Emirates	--	--	3	30	6	50	--	--	9	80
United Kingdom	--	--	11,500	55,300	5,020	45,700	(4/)	2	16,500	101,000
Uruguay	--	--	--	--	6,240	60,900	0	0	6,240	60,900
Total	65	636	39,000	292,000	184,000	1,680,000	60	1,800	223,000	1,980,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes base metal ores, concentrates, and matte destined for refining.

3/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.

4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY 1/

Year and country	Waste and scrap		Metal powder		Gold compounds	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1999	30,500	$94,100	5,500	$48,700	9,400	$59,700
2000:						
Australia	4	40	10	82	--	--
Austria	2	26	--	--	--	--
Belgium	--	--	--	--	1	4
Bolivia	267	1,930	--	--	--	--
Brazil	13	48	--	--	1,550	9,210
Canada	2,340	15,200	6,150	54,500	--	--
China	11	96	--	--	--	--
Colombia	47	387	--	--	5,700	48,600
Costa Rica	955	3,420	4	40	8	59
Cote d'Ivoire	--	--	10	51	--	--
Dominican Republic	9,990	22,800	20	155	--	--
Ecuador	302	1,210	--	--	--	--
El Salvador	2	10	--	--	--	--
France	12	84	--	--	--	--
Gambia, The	--	--	(2/)	2	--	--
Germany	116	103	10	82	16	37
Ghana	--	--	89	870	--	--
Guatemala	7	36	--	--	--	--
Honduras	17	177	225	1,950	--	--
Hong Kong	80	638	--	--	--	--
Ireland	(2/)	3	--	--	51	660
Israel	3	29	1	3	--	--
Italy	2	23	(2/)	3	74	63
Japan	18	118	1	13	316	174
Korea, Republic of	13	97	--	--	--	--
Liberia	--	--	1	10	--	--
Malaysia	518	4,420	--	--	--	--
Mali	--	--	8	70	--	--
Mexico	3,400	13,700	6	95	--	--
Nambia	6	35	--	--	--	--
Netherlands	22	201	(2/)	3	19	14
Netherlands Antilles	19	104	--	--	--	--
Panama	119	638	--	--	--	--
Peru	9	26	--	--	170	1,520
Philippines	38	275	--	--	--	--
Sierra Leone	--	--	150	577	--	--
Singapore	15	130	1	21	10	127
Slovakia	7	62	--	--	--	--
Spain	2	20	--	--	--	--
St.Kitts and Nevis	(2/)	3	--	--	--	--
St. Vincent and the Grenadines	31	32	--	--	--	--
Switzerland	--	--	29	219	--	--
Taiwan	27	167	7	43	--	--
Thailand	7	27	--	--	--	--
United Arab Emirates	2	14	--	--	--	--
United Kingdom	11,300	4,700	3	24	57	70
Venezuela	23	195	--	--	--	--
Total	29,800	71,200	6,720	58,800	7,970	60,500

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 8
GOLD: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country	1996	1997	1998	1999	2000 e/
Argentina	723	2,289	20,400	38,515	26,000
Armenia e/	244 3/	500	350	400	400
Australia	289,530	314,500	310,070	301,070	296,410 3/
Belize e/	5	5	6	6	6
Bolivia	12,634	13,292	14,444	11,787	11,001 3/
Botswana	5	28	1	2 r/	4
Brazil 4/	60,011	58,488	49,567	52,634 r/	52,000 p/
Bulgaria	3,390 e/	1,020	1,250 r/	1,030 r/	1,100
Burkina Faso	1,063 r/	1,089 r/	1,091 r/	886 r/	1,000
Burundi e/	2,200	1,500	1,500	1,500	1,500
Burma	172 r/	181 r/	172 r/	242 r/	250
Cameroon e/	1,000	1,000	1,000	1,000	1,000
Canada	166,378	171,479	165,599	157,617 r/	153,781 3/
Central African Republic e/	90	90	100	100	100
Chile	53,174	49,459	44,980	45,663	54,142 3/
China e/	145,000	175,000	178,000	173,000 r/	180,000
Colombia	22,073	18,811	18,813	19,000 e/	19,000
Congo (Brazzaville) e/	10	10	10	10	10
Congo (Kinshasa) e/	8,200	9,600	4,800	4,000	4,000
Costa Rica	510 e/	502	483	300 e/	350
Cote d'Ivoire	1,883 5/	2,419 5/	3,400	2,717 r/	3,154 3/
Cuba e/	250	250	1,000	1,000	1,000
Dominican Republic	3,659	2,349	1,424	651	650
Ecuador e/ 5/	7,208 3/	3,070	3,500	4,000	4,000
El Salvador	--	110	98	100	100
Eritrea	98	612 r/	573	570 r/ e/	500
Ethiopia 6/	2,500 5/	3,000 e/	2,500	5,000 r/ e/	2,000
Fiji	4,452	4,671	3,690	4,491 r/	3,675 3/
Finland	3,070	3,900 r/	5,000 r/ e/	5,900 r/ e/	5,000
France	5,651	4,953 r/	3,793 r/	3,600 r/ e/	3,000
French Guiana (Guyane) e/	3,000	3,000	3,000	3,000	3,000
Gabon e/ 7/	70	70	70	70	70
Georgia e/	500	700	700	2,000	2,000
Ghana	49,211	54,662	72,541 r/	79,946 r/	72,080
Guatemala e/	30	100	100	50	50
Guinea	6,838	7,100	11,700	13,300 e/	13,000
Guyana	12,006	13,521	13,500 e/	13,500 e/	13,500
Honduras e/	142 3/	150	150	150	150
India 8/	2,449	2,750	2,383	2,500 r/	4,800 3/
Indonesia 9/	83,564	86,927	124,018	127,184 r/	124,596 3/
Iran	640	684	822	800 e/	800
Italy	--	--	1,200	1,000	1,000
Japan	8,627	8,384	8,601	9,405	9,000
Kazakhstan e/	12,500	18,700 r/	18,100 r/	19,982 r/ 3/	20,000
Kenya	492 r/	440	388	990 3/	990
Korea, North e/	5,000	5,000	5,000	5,000	5,000
Korea, Republic of 8/	14,096	14,852	22,822	25,730	25,000
Kyrgyzstan e/	1,500	17,400 3/	22,000	20,000	20,000
Liberia e/	700	500	800	1,000	1,000
Madagascar e/	50	50	50	50	50
Malaysia	2,830	4,487	3,394	3,449	4,026 p/ 3/
Mali	4,329 r/	16,323 r/	20,562 r/	23,688 r/	25,000
Mauritania	189	--	--	--	--
Mexico	24,477	26,001	25,427	23,755 r/	26,375 3/
Mongolia	6,976	8,451	10,040	10,038	10,000
Morocco e/	482 3/	450	450	450	450
Mozambique	67	6	17	20	20
Namibia	2,145	2,417	1,882	2,100 e/	2,100
New Zealand	11,879	11,359	7,544 r/	8,577 r/	8,600
Nicaragua	1,500 e/	2,562	3,834	2,700 e/	2,800
Niger e/	1,000	1,000	1,000	1,000	1,000
Nigeria e/	6	6	10	10	10
Oman	576	575	575 e/	575 e/	575

See footnotes at end of table.

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TABLE 8--Continued
GOLD: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country	1996	1997	1998	1999	2000 e/
Panama	834	1,202	1,500 e/	1,500 e/	1,500
Papua New Guinea	51,119	45,418	64,106	61,293	74,000
Peru 10/	64,788	79,117 r/	94,214 r/	128,486 r/	132,585 3/
Philippines	30,180 r/	32,671 r/	34,038	31,031 r/	30,000
Poland	598	435	600 e/	600 e/	600
Romania e/	4,000	4,000	4,000	4,000	4,000
Russia	123,300 r/	124,000 r/ e/	114,900 r/	125,870 r/	140,000
Rwanda	1 r/	10 r/	17 r/	10 r/	10 3/
Saudi Arabia	7,530	7,260	9,000	9,000 e/	9,000
Senegal e/	600	550	600	400	400
Serbia and Montenegro e/	3,000	3,000	2,684	1,260	1,200
Sierra Leone 11/	16	20 r/	15	30 e/	30
Slovakia	540	458	340	300	300
Solomon Islands e/	25	25	1,565 r/ 3/	3,456 r/	338 3/
South Africa	496,846	491,680	464,319	451,300 r/ 3/	430,778 3/
Spain	2,832 r/	1,824	3,295	5,081 r/	5,000
Sudan e/	4,500	4,554 r/ 4/	5,653 r/ 4/	6,000	6,000
Suriname e/	300	300	300	300	300 12/
Sweden e/	6,500	6,100	6,000	6,000	6,000
Taiwan 8/	11	9	9 r/ 3/	13 r/	12
Tajikistan	1,100 e/	2,550	3,000	2,700 e/	2,700
Tanzania	318	300	720	6,100 e/	6,100
Turkey e/ 13/	1,200	1,000	1,000	1,200	1,200
Uganda	3 r/	6 r/	8 r/	5 r/	56 3/
United States	326,000	362,000	366,000	341,000	353,000
Uruguay e/	1,000	2,800 r/	1,985 3/	2,400 r/	2,300
Uzbekistan e/	72,000	81,700	80,000 3/	85,000 3/	85,000
Venezuela	11,719	22,322	6,740 r/	5,946 r/	7,332 3/
Vietnam e/	1,000	1,000	1,500 r/	1,500 r/	2,000
Zambia 14/	119	290 e/	765	700 r/ e/	600
Zimbabwe	24,772	24,156	25,175	27,666 r/	22,070 3/
Total	2,290,000 r/	2,450,000	2,510,000 r/	2,550,000 r/	2,550,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through August 11, 2000.

3/ Reported figure.

4/ Officially reported figures are as follows, in kilograms: Major companies: 1996--41,142; 1997--41,062; 1998--41,000 (estimated); and 1999-2000-not available. Garimpos 1995--23,473; 1996--18,869; 1997--17,426; 1998--17,500 (estimated); and 1999-2000--not available.

5/ Includes undocumented artisanal production.

6/ Year ending July 7 of that stated.

7/ Undocumented artisanal production.

8/ Refinery output.

9/ Excludes production from so-called people's mines, which may be as much as 18,000 kilograms per year, but includes gold recovered as byproduct of copper mining.

10/ Includes documented production from placer artisanal production.

11/ Data are based on official exports and do not reflect gold moved through undocumented channels.

12/ Government estimates unreported production as high as 30,000 kilograms.

13/ Indicates byproduct of base metals.

14/ Year beginning April 1 of that stated. Byproduct of copper production by Zambia Consolidated Copper Mines Ltd. only. Some additional artisan production was reported, but data are insufficient to make reliable estimates.

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GRAPHITE

By Rustu S. Kalyoncu

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Graphite is one of three forms of crystalline carbon; the other two are diamond and fullerenes. Graphite occurs naturally in metamorphic rocks such as marble, schist, and gneiss. It is a soft mineral, also known by the names of black lead, plumbago, and mineral carbon. The word graphite is derived from the Greek word "graphein," to write. It has a Mohs hardness of 1 to 2 and exhibits perfect basal cleavage. Depending upon the purity, the specific gravity is 2.20 to 2.30. The theoretical density is 2.26 grams per cubic centimeter. It is gray to black in color, opaque, and has a metallic luster. It is flexible but not elastic. It has high thermal and electrical conductivities, is highly refractory, and is chemically inert.

Two general types of graphite, natural and synthetic, are encountered. Worldwide, natural graphite deposits occur as lenses or layers of disseminated or massive flakes. Graphitization of naturally occurring organic carbon may occur at temperatures as low as 300° C to 500° C or as high as 800° C to 1,200° C, such as when an igneous intrusion contacts a carbonaceous body.

The three principal types of natural graphite—lump, crystalline flake, and amorphous—are distinguished by physical characteristics that are the result of major differences in geologic origin and occurrence. Lump graphite occurs in veins and is believed to be hydrothermal in origin. It is typically massive, ranging in particle size from extremely fine to coarse, platy intergrowths of fibrous or acicular crystalline aggregates with the long axis parallel to the enclosing wall rock (Kenan, 1984). Crystalline flake graphite consists of isolated, flat, plate-like particles with angular, rounded, or irregular edges. It is usually found in layers or pockets in metamorphic rocks. In some deposits, the flake graphite occurs as massive accumulations in veins, lenses, or pods. Amorphous graphite is formed by the thermal metamorphism of coal. The designation amorphous is a misnomer. Its relatively low degree of crystalline order and very fine particle size make it appear amorphous. It is usually of lower purity than the crystalline flake graphite and, therefore, commands a lower price than its more ordered counterpart.

Beneficiation processes for graphite may vary from a complex four-stage flotation at the European and U.S. mills to simple hand sorting and screening of high-grade ore at the Sri Lanka operations. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Typically, such ores contain the highest proportion of coarse flakes. Ore is sluiced to the field washing plant where it undergoes desliming to remove clay fractions and is subjected to a rough flotation to produce a concentrate with 60% to 70% carbon. This concentrate is transported to the refining mill for further grinding and flotation to reach 85% carbon and screened to a variety of products marketed as flake graphite containing 75% to 90% carbon.

Legislation and Government Programs

Total national defense stockpile graphite inventories, including nonstockpile-grade, were 8,730 metric tons (t) with a value of about $1.65 million. Madagascar natural graphite inventories in the United States were 3,870 t with a value of

Graphite in the 20th Century

In 1900, 555 metric tons of graphite valued at $198,000 was produced in the United States. Michigan, New York, Pennsylvania, Rhode Island, and Wisconsin were the only graphite producing States in 1900. In contrast to production, 14,000 tons of graphite valued at $1.4 million were imported. Imports were mostly from Ceylon. In the early 1900s, natural graphite found uses in the manufacture of lead pencils, lubricants, and few electrical applications. Such uses continued throughout the mid-1950s.

There has been no graphite mined in the United States since 1990, when United Minerals Co. suspended its graphite mining operations at its Montana mine, but 60,800 tons of natural graphite was imported, mainly, in decreasing order, from China, Canada, Brazil, Mexico, and Madagascar. In 2000, the United States produced 290,000 tons of synthetic graphite valued at $771 million, and exported 94,000 tons of graphite products at a value of $97 million. Today, with the development of techniques to synthesize graphite from organic materials and advanced purification methods for natural graphite, there are myriad applications for both natural and synthetic graphite. Natural graphite of 99.8% purity can compete with synthetic graphite in a number of applications such as fiber composites. Developments in the area of materials engineering and the ability to process fibers and synthesize graphite from organic precursors have made graphite truly a high technology material that has uses such as high-strength graphite fiber composites for space age applications. The next important development in the use of graphite will come in the energy field: advanced automotive batteries and fuel cells. Fuel cells alone, once fully developed and marketed, will account for more than half the graphite consumption in the United States.

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$600,000. There were 4,810 t of Sri Lanka amorphous lump with a value of $1.10 million (table 2). No acquisition of graphite for the strategic and critical materials stockpile occurred in 2000. Graphite no longer has a Government stockpile goal and all graphite in the Government stockpile has been authorized for sale.

Production

No graphite was mined in the United States in 2000. The reported U.S. production of synthetic graphite reached 290,000 t with a value of $771 million (table 4).

Graphite is mined from open pit and underground mine operations. Open pit operations are more economical and, thus, are preferred where the overburden can be removed economically. Mines in Madagascar are mostly of this type. In the Republic of Korea, Mexico, and Sri Lanka, where the deposits are deep, underground mining techniques are required.

Consumption

The use of graphite has changed dramatically. Graphite exhibits the properties of a metal and a nonmetal, which makes it suitable for many industrial applications. The metallic properties include thermal and electrical conductivity. The nonmetallic properties include inertness, high thermal resistance, and lubricity. The combination of conductivity and high thermal stability allows graphite to be used in many applications such as refractories, batteries, and fuel cells. Lubricity and thermal conductivity make it an excellent material for high-temperature applications, because it results in a material that provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface. Lubricity and electrical conductivity allow its use as the primary material in the manufacture of brushes for electric motors. A graphite brush effectively transfers electric current to a rotating armature while the natural lubricity of the brush minimizes frictional wear. Today's high technology products, such as friction materials and battery and fuel cells, demand higher purity graphite.

U.S. consumption of natural graphite increased by more than 20% in 2000 to 41,800 t from 34,600 t in 1999 (table 3). The crystalline grade increased in 2000 by only 3.5% to 17,900 t from 17,300 t in 1999, whereas amorphous grade increased by an impressive 38% in 2000 to 23,900 t from 17,300 t in 1999. This increased use translated into a more than 50% increase in value in 2000.

The four major industries—refractories, brake linings, lubricants, and foundries—for which natural graphite is used continued their dominance in graphite usage, accounting for one-half of the graphite consumed by U.S. industry in 2000 (table 3). The refractories industry was again the major consumer of crystalline flake graphite followed by the manufacture of brake linings and metal powders. Refractory applications of graphite included castable ramming, gunning mixtures, and carbon-bonded brick. Carbon-magnesite brick has applications in high-temperature corrosive environments such as steel furnaces, ladles, and iron blast furnaces. Carbon-alumina linings are principally used in continuous steel-casting operations. Magnesite- and alumina-carbon brick requires a particle size of 100 mesh and a purity of 95% to 99% graphite.

Crystalline flake graphite accounted for nearly 45% of graphite usage in the United States. It was used mainly in refractories, batteries, and other thermal and electrical conductivity applications. Amorphous graphite is mainly used as a lubricant additive, as a pigment in paints; in plastic refractories, and in other applications where additions of graphite improve the process or the end product. Lump graphite finds appropriate uses in a number of areas, such as steelmaking, depending on the purity and particle size.

Synthetic graphites remain the choice in North America, accounting more than half of the market. The main market for high purity synthetic graphites is iron and steel as a carbon-raiser additive. This market consumes more than 50% of the synthetic graphite.

Other significant uses of all types of graphites are in the manufacture of low-current, long-life batteries, steelmaking, solid carbon shapes, static and dynamic seals, valve and stem packing, catalyst supports, porosity enhancing inert fillers, manufacture of rubber, and powder metallurgy. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical.

Prices

Graphite prices remained unchanged during 2000. Prices for crystalline flake graphite concentrates ranged from $480 to $550 per metric ton and commanded higher prices than the amorphous, which was priced at $220 to $235 per ton (table 5). Carbon content, flake and crystal size, size distribution, and ash content affect the price of graphite. The price of synthetic graphite, however, declined to $1.94 per kilogram in 2000 from $2.29 per kilogram in 1999. Customary negotiations between the buyer and the seller lead to wide price fluctuations.

Foreign Trade

Total imports of natural graphite increased in tonnage to 60,800 t in 2000 from 55,800 t in 1999, but the value declined to $32.5 million in 2000 compared with $34.7 million in 1999 (table 7). Principal import sources of natural graphite were China, Canada, Mexico, Japan, Madagascar, and Brazil, in order of tonnages, which accounted for 89% of the value of total imports. Mexico continued to be the major supplier of amorphous graphite and Sri Lanka provided the lump variety. A number of other producers supplied various types and grades of graphite to the United States, among the more notable being Japan and Germany.

In spite of showing a noticeable decrease in tonnage, total exports recorded an impressive 16% increase in total revenue to $96.5 million in 2000 compared with $82.8 million in 1999 because of the increase in value of the finished goods exported (table 6).

World Review

World production of graphite in 2000 was estimated to be 602,000 t compared with 600,000 t in 1999. China maintained

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its position as the world's leading graphite producer with 220,000 t, with India in second place with 140,000 t, followed by Brazil, Mexico, and the Czech Republic, in order of importance. These five countries accounted for over three-quarters of the world production (table 9).

Sri Lanka continued to account for nearly all the high-purity lump graphite produced. Sri Lankan deposits were estimated to average 95% graphite in situ. China accounted for 37% of world production.

Current Research and Technology

In recent years, new technology in processing and treatment has expanded the use of natural graphites in battery applications. Graphite for these applications is purified to 99.9% carbon. Most new uses for graphite products are being developed through advances in graphite thermal technology. The ability to refine and modify graphite and carbon products will be the key to future growth in the graphite industry. Innovative refining techniques have enabled the use of improved graphite in friction materials, electronics, foil, and lubrication applications (Hand, 1997). Some of the new application areas include electrically conductive asphalt for heated runways at airports and roadway bridges.

With its low specific gravity, refractoriness, and corrosion resistance, graphite is critical for many industrial applications, such as dies for continuous casting, rocket nozzles, and heat exchangers for the chemical industry. Relatively poor wear and oxidation resistance of graphite, however, limit its use. A class of high-performance materials based on titanium carbide-coated graphite makes the material suitable for some of the most demanding applications (Webb, 2000). Because titanium carbide is one of the hardest and most durable materials, the resulting components are extremely resistant to wear, corrosion, and elevated temperatures. These composites can be engineered to fit many industrial uses through control of the coating composition, thickness, microstructure, and surface finish. In metal melting applications titanium carbide coatings have been shown to improve the service life of the graphite components by as much as fivefold.

Advanced refining technology in the next few years, despite a weak refractory market and pricing pressure from Chinese material, could bring a reversal of fortune to the graphite industry.

Enigmatic clusters of carbon atoms, called fullerenes, which are found as large carbon-cage molecules, have been puzzling scientists since 1985 when they were first discovered among the byproducts of laser-vaporized graphite (Pierson, 1993). Their hollow spherical structure, reminiscent of geodesic domes of architect Buckminster Fuller, earned them the names "buckyballs" and "fullerenes." Mistakenly called a new form of carbon, fullerenes have been found to exist in interstellar dust as well as in geological formations on Earth. Fullerenes are fascinating because they exhibit unusual properties for carbon materials. For example, adding 3 alkali atoms per fullerene unit (C_{60}) results in a material that exhibits superconductivity at quite high temperatures (10° K to 40° K). These materials also exhibit lubricity superior to that of graphite. To date, no product based on fullerenes has been offered in the market. The full potential of fullerenes in practical applications remains to be explored.

Outlook

The main areas of natural graphite consumption in the near future will be in high temperature applications for the iron and steel industry as the industry modernizes its production facilities. Brake linings and other friction materials will steadily consume more natural graphite as new automobile production continues to increase and more replacement parts are required for the growing number of vehicles. Flexible graphite product lines, such as grafoil (a thin graphite cloth), will probably be the fastest growing market but will consume small amounts of natural graphite compared with major end-use markets.

The advent of hybrid and electric vehicles is expected to bring increased demand for high-purity graphite in fuel cell and battery applications. One optimistic prediction is that the demand for high quality, high carbon graphite could increase to more than 100,000 metric tons per year (t/yr) for fuel cell and battery applications alone (Crossley, 2000). The global demand for graphite used in batteries may double to more than 25,000 t/yr in the next 5 years. This demand is expected to be spread between the two main consuming sectors-alkaline batteries and lithium-ion batteries. Synthetic and natural graphite are both used in these batteries.

In alkaline batteries, graphite is the conductive material in the cathode. Until recently, synthetic graphite was dominantly used in these batteries. But with the advent of new purification techniques and more efficient processing methods, it has become possible to improve the conductivity of most natural graphite to the point where it can be used in batteries. The decision whether to use synthetic or natural graphite will be a balancing act between price and performance. The growth of the lithium-ion battery market could have a more dramatic effect on the graphite market as the demand rises for mobile energy storage systems.

Fuel cells convert hydrogen into electricity by an electrochemical reaction. The hydrogen molecules break down into protons and electrons at the cell's anode. Protons are then conducted through the electrode and the electrons travel through an external circuit and generate electricity. Graphite, as cathode material, forms a crucial part of fuel cell technology. Some predictions show that consumption of graphite in fuel cell electrodes could reach 80,000 t/yr in just 2 to 3 years. Canada, Germany, Japan, and the United States are aggressively promoting fuel cell development. The cost of fuel cells, however, is still too high for commercial vehicles. The price per unit needs to drop to about $1,500 before they will be viable. Daimler-Chrysler Corporation has pledged to have a commercially viable fuel cell vehicle by 2004, and trials for fuel cell buses, taxis, and bicycles have already begun.

In the event of any price increases, China may increase its production to take advantage of potentially increased profits, leading to a sharp price decline in certain grades and possibly to a production stoppage in other countries. If the Chinese iron and steel industry, however, expands its consumption of natural graphite, Chinese exports may eventually decline, encouraging new producers to enter the market (Roskill Information

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Services Ltd., 1998).

Industry trends that appear to be common to advances in graphite technology and markets include higher purity and consistency in specifications for some specialized and high-tech applications. Production of higher purity graphite using thermal processing and acid leaching techniques continues to be the trend. This material has applications as advanced carbon-graphite composites.

References Cited

Crossley, Peter, 1999, Graphite—High-tech supply sharpens up: Industrial Minerals, no. 386, Nov 1999, p. 31-47.

Hand, G.P., 1997, Outlook for graphite and graphite technology: Mining Engineering, v. 49, no. 2, February, p. 34-36.

Kenan, W.M., 1984, Economics of graphite. Society of Mining Engineers. American Institute of Mining, Metallurgical, and Petroleum Engineers preprint no. 84-300, 3 p.

Pierson, H.O., 1993, Handbook of carbon, graphite, diamond, and fullerenes—Properties, processing, and applications: New York, Noyes Data, 405 p.

Roskill Information Services Ltd., 1998, The economics of natural graphite, 5th ed.: Roskill Information Services Ltd., London, 130 p.

Webb, Robert, 2000, TiC-coated graphite designed with properties tailored to various applications: Industrial Heating, v. 6, no. 5, p. 47-48.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Graphite. Ch. in Mineral Commodity Summaries, annual.

Graphite. Ch. In United States Mineral Resources, Professional Paper 820, 1973.

Natural Graphite. International Strategic Minerals Inventory Summary Report, Circular 930-H, 1988.

Other

Chemical Week.

European Chemical News.

Industrial Minerals (London).

TABLE 1
SALIENT NATURAL GRAPHITE STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Apparent consumption 2/	metric tons	27,400	18,400	33,600	26,400	39,000
Exports	do.	26,000	39,700	28,000	29,400	21,800
Value	thousands	$14,600	$20,500	$14,100	$15,200	$12,500
Imports for consumption	metric tons	53,400	58,100	61,600	55,800	60,800
Value	thousands	$28,600	$32,400	$34,800	$34,700	$32,500
World production	metric tons	555,000 r/	685,000 r/	646,000 r/	600,000 r/	602,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Domestic production plus imports minus exports.

TABLE 2
U.S. GOVERNMENT STOCKPILE YEAREND STOCKS OF NATURAL GRAPHITE IN 2000, BY TYPE 1/ 2/

(Metric tons)

Type	Stock
Madagascar crystalline flake	3,870
Sri Lanka amorphous lump	4,810
Nonstockpile-grade, all types	49

1/ Graphite no longer has a goal.

2/ Data are rounded to no more than three significant digits.

Source: Defense National Stockpile Center, Inventory of Stockpile Material as of December 31, 2000.

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TABLE 3
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE 1/

End use	Crystalline		Amorphous 2/		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:						
Batteries	W	W	--	--	W	W
Brake linings r/	1,090	$1,290	5,280	$4,540	6,380	$5,830
Carbon products 3/	425	1,310	318	268	743	1,570
Crucibles, retorts, stoppers, sleeves, nozzles	W	711	W	W	W	W
Foundries 4/	W	494	1,780	825	W	1,320
Lubricants 5/	328	580	1,190 r/	911 r/	1,510	1,490
Pencils	W	W	W	W	W	W
Powdered metals	435 r/	1,000 r/	W	W	W	W
Refractories	W	W	5,580	3,670	W	W
Rubber	W	844	W	367	W	1,210
Steelmaking	W	W	W	W	W	W
Other 6/	W	W	788	510	W	W
Total	17,300	18,800	17,300	12,200 r/	34,600	31,000
2000:						
Batteries	W	W	--	--	W	W
Brake linings	1,100	1,340	5,480	4,010	6,580	5,350
Carbon products 3/	471	1,390	W	210	W	1,600
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries 4/	W	584	W	W	W	W
Lubricants 5/	389	649	1,180	883	1,570	1,530
Pencils	W	W	W	W	W	W
Powdered metals	437	1,010	W	W	W	W
Refractories	5,310	W	5,360	3,590	10,700	W
Rubber	W	W	W	W	W	W
Steelmaking	28	18	W	W	W	W
Other 6/	W	W	812	541	W	W
Total	17,900	19,400	23,900	18,500	41,800	38,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

1/ Data are rounded to no more than three significant digits.

2/ Includes mixtures of natural and manufactured graphite.

3/ Includes bearings and carbon brushes.

4/ Includes foundries (other) and foundry facings.

5/ Includes ammunition and packings.

6/ Includes antiknock and other compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, paints and polishes, small packages, soldering/welding, and other end-use categories.

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TABLE 4
U.S. PRODUCTION OF SYNTHETIC GRAPHITE, BY END USE 1/

End use	Quantity (metric tons)	Value (thousands)
1999:		
Anodes	W	W
Cloth and fibers (low modulus)	W	$82,500 r/
Electric motor brushes and machined shapes	5,380	32,400
Electrodes	172,000	535,000
High-modulus fibers	2,450	54,400
Unmachined graphite shapes	4,870 r/	44,600 r/
Synthetic graphite powder and scrap 2/	W	W
Other	W	W
Total	267,000	823,000 r/
2000:		
Anodes	W	W
Cloth and fibers (low modulus)	W	90,700
Electric motor brushes and machined shapes	W	22,300
Electrodes	188,000	471,000
High-modulus fibers	W	W
Unmachined graphite shapes	5,980	57,300
Synthetic graphite powder and scrap 2/	84,500	46,700
Other	W	W
Total	290,000	771,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits.
2/ Includes lubricants (alone/in greases), steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 5
REPRESENTATIVE YEAREND GRAPHITE PRICES 1/

(Per metric ton)

Type	1999	2000
Crystalline large flake, 94% carbon	$570-$750	$570-$750
Crystalline large flake, 90% carbon	480-550	480-550
Crystalline medium flake, 90% carbon	370-410	370-410
Crystalline small flake, 80% to 95% carbon	270-500	270-500
Amorphous powder, 80% to 85% carbon	220-235	220-235
Synthetic, 99.95% carbon, Swiss border	2,290	1,940

1/ Prices are normally cost, insurance, and freight (c.i.f.) main European port.

Source: Industrial Minerals, no. 387, December 1999, p. 70; no. 399, December 2000, p. 74.

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TABLE 6
U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY 1/ 2/

Country	Natural 3/		Artificial 4/		Total	
	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)
1999:						
Australia	267	$342	1,670	$1,620	1,940	$1,960
Bangladesh	6,240	2,160	--	--	6,240	2,160
Belgium	60	23	1,270	962	1,330	985
Brazil	38	13	1,580	2,110	1,620	2,120
Canada	5,410	3,570	8,290	12,800	13,700	16,300
France	4	16	3,740	5,590	3,750	5,600
Germany	207	128	1,110	1,410	1,320	1,540
Hong Kong	1,200	557	236	274	1,430	831
Italy	68	69	3,920	3,790	3,990	3,860
Japan	328	240	15,600	8,190	16,000	8,430
Korea, Republic of	238	202	8,470	4,870	8,710	5,080
Malaysia	231	135	908	2,140	1,140	2,270
Mexico	8,090	3,130	3,220	2,310	11,300	5,440
Netherlands	2,270	889	10,400	4,070	12,700	4,960
Sweden	54	39	1,390	1,900	1,440	1,940
Switzerland	1,200	521	47	146	1,250	667
Taiwan	674	414	1,080	1,390	1,760	1,800
United Kingdom	299	227	3,070	2,750	3,370	2,980
Venezuela	1,490	1,750	711	983	2,200	2,730
Other r/ 6/	1,010	794	5,770	10,400	6,780	11,200
Total	29,400	15,200	72,600 r/	67,600	102,000	82,800
2000:						
Aruba	1,020	347	--	--	1,020	347
Australia	187	207	1,340	2,300	1,530	2,510
Belgium	144	72	1,140	1,390	1,280	1,460
Brazil	40	20	1,310	2,900	1,350	2,920
Canada	4,750	4,550	7,940	13,600	12,700	18,100
France	19	62	2,450	10,400	2,470	10,500
Germany	78	129	1,620	2,260	1,690	2,390
Hong Kong	1,270	658	567	448	1,840	1,110
Israel	710	252	874	1,250	1,580	1,500
Italy	180	256	1,510	3,310	1,690	3,560
Japan	64	113	17,100	9,710	17,200	9,830
Korea, Republic of	360	226	5,370	5,130	5,740	5,350
Mexico	2,370	1,200	4,370	5,520	6,740	6,720
Netherlands	4,170	1,430	17,000	7,500	21,100	8,930
Spain	247	202	779	998	1,030	1,200
Switzerland	2,920	614	100	205	3,020	819
Taiwan	1,130	777	336	470	1,470	1,250
United Kingdom	482	400	3,270	4,720	3,750	5,120
Other 6/	1,710	1,020	5,250	11,900	6,950	12,900
Total	21,800	12,500	72,300	84,000	94,100	96,500

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Numerous countries for which data were reported have been combined within the "Other" category under the "Country" list.

3/ Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Harmonized Tariff Schedule (HTS) nomenclature titles and codes are: "Natural graphite in powder or in flakes" and "Other," HTS codes 2504.10.0000 and 2504.90.0000.

4/ Includes data from the applicable HTS nomenclatures: "Artificial graphite" and "Colloidal or semicolloidal graphite," HTS codes 3801.10.0000 and 3801.20.0000.

5/ Values are free alongside ship (f.a.s.).

6/ Includes data for countries reflecting less than 1,000 metric tons of total exports from the United States.

Source: U.S. Census Bureau.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY 1/ 2/

Country or territory	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude, high-purity, expandable		Amorphous		Total	
	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)
1999:										
Brazil	38	$46	--	--	4,710	$9,440	--	--	4,750	$9,490
Canada	12,600	7,510	--	--	1	26	--	--	12,600	7,540
China	8,180	3,360	--	--	9,720	5,180	741	$170	18,600	8,710
Germany	--	--	--	--	182	519	--	--	182	519
India	24	25	--	--	--	--	--	--	24	25
Japan	21	12	--	--	384	2,120	491	28	896	2,160
Madagascar	2,570	1,370	--	--	--	--	--	--	2,570	1,370
Mexico	--	--	--	--	570	264	12,500	1,820	13,100	2,080
Mozambique	1,190	1,050	--	--	--	--	--	--	1,190	1,050
Sri Lanka	--	--	418	$530	--	--	--	--	418	530
Zimbabwe	200	81	--	--	--	--	--	--	200	81
Other 4/	815	552	--	--	207	581	216	53	1,240	1,190
Total	25,600	14,000	418	530	15,800	18,100	14,000	2,070	55,800	34,700
2000:										
Brazil	675	808	--	--	1,050	2,020	324	73	2,040	2,900
Canada	14,300	8,540	--	--	18	60	--	--	14,300	8,600
China	6,570	4,440	--	--	10,100	4,330	2,250	327	19,000	9,100
Germany	7	7	--	--	83	210	--	--	90	217
India	150	137	--	--	--	--	--	--	150	137
Japan	9	12	--	--	454	4,130	4,600	358	5,060	4,500
Madagascar	3,690	1,780	--	--	--	--	349	101	4,040	1,880
Mexico	--	--	--	--	415	202	13,900	1,900	14,300	2,100
Mozambique	196	111	--	--	--	--	--	--	196	111
Sri Lanka	--	--	265	330	--	--	--	--	265	330
Zimbabwe	180	95	--	--	--	--	--	--	180	95
Other 4/	486	172	--	--	821	2,340	--	--	1,310	2,510
Total	26,200	16,100	265	330	13,000	13,300	21,400	2,760	60,800	32,500

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The information framework from which data for this material were derived originated from Harmonized Tariff Schedule (HTS) base data.

3/ Customs values.

4/ Includes Austria (2000), Belgium (2000), Dominican Republic (1999), Finland (2000), France, Hong Kong, Indonesia (2000), Italy, the Marshall Islands (2000), the Netherlands, Russia (2000), Seychelles (2000), South Africa, Sweden (1999), Switzerland (2000), Taiwan (2000), Ukraine (1999), and the United Kingdom.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION
OF GRAPHITE ELECTRODES, BY COUNTRY 1/ 2/

Country	Quantity (metric tons)	Value 3/ (thousands)
1999:		
Brazil	4,890	$11,700
Canada	9,010	22,300
China	1,980	3,490
Germany	3,360	9,450
India	3,480	7,130
Italy	6,700	13,500
Japan	8,730	25,900
Mexico	17,500	28,300
Russia	3,630	4,930
Switzerland	1,680	3,860
Other 4/	1,910	4,490
Total	62,800	135,000
2000:		
Brazil	6,480	13,500
Canada	6,000	15,900
China	2,990	5,070
Germany	4,110	9,970
India	2,700	5,880
Italy	4,380	7,830
Japan	11,100	30,500
Mexico	17,300	29,200
Russia	3,350	4,620
Other 4/	2,450	5,370
Total	60,900	128,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The applicable Harmonized Tariff Schedule (HTS) code and nomenclature title are HTS 8545.11.0000, "Electric Furnace Electrodes."
3/ Customs values.
4/ Includes data for countries reflecting less than 1,000 metric tons per year for imports.

Source: U.S. Census Bureau.

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TABLE 9
GRAPHITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Austria e/	12,000	12,000	12,000	12,000	12,000
Brazil (marketable)	31,254	40,587	61,369	56,200 r/	56,000
Canada e/ 3/	25,000	25,000	25,000	25,000	25,000
China e/	185,000	310,000	224,000 r/	217,000 r/	220,000
Czech Republic e/	30,000	25,000	28,000	22,000 r/	25,000
Germany (marketable)	2,603	1,030	1,000 e/	1,000 e/	1,000
India (run-of-mine) 4/	115,233	102,143	143,333	145,000 e/	140,000
Korea, North e/	40,000	40,000	35,000	25,000	25,000
Korea, Republic of	1,113	83	62	62 r/	60
Madagascar 5/	12,134	13,975	13,087 r/	13,000 r/ e/	13,000
Mexico:					
Amorphous	38,967	46,707	42,893	27,781 r/	30,330 p/
Crystalline flake	1,445	1,275	568	-- r/	--
Mozambique	3,283	5,125	5,889	2,100 r/ e/	--
Norway e/	2,600 r/	2,600	2,600 r/	2,500	2,500
Romania	2,931	2,563	1,951 r/	1,041 r/	1,500
Russia e/	6,000	6,000	6,000	6,000	6,000
Sri Lanka	5,618	5,400 r/	5,910 r/	4,592 r/	4,600
Sweden	463	1,470	3,011	4,500	5,000
Tanzania e/	6,776 6/ 7/	11,000	-- 8/	--	--
Turkey (run-of-mine) e/ 9/	20,000	15,000	15,000	15,000	15,000
Ukraine	5,000 r/ e/	5,000 r/ e/	5,104 r/	7,461 r/	7,500
Uzbekistan e/	60	60	60	60	60
Zimbabwe	7,691	12,779	13,806	12,321 r/	12,000
Total	555,000 r/	685,000 r/	646,000 r/	600,000 r/	602,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 11, 2001.

3/ Source: World Mineral Statistics, British Geological Survey, 1995-99.

4/ Does not include the following quantities sold directly without beneficiation, in metric tons: 1996--4,134; 1997--9,397; 1998--10,747; 1999--10,700 (estimated); and 2000--10,500 (estimated).

5/ Indian marketable production is 10% to 20% of run-of-mine production.

6/ Reported figure.

7/ Exports. Source: United Nations, Department of International Economic and Social Affairs, Statistical Office.

8/ Graphtan Limited Mine closed. Only remaining stocks shipped in January-February 1998.

9/ Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.

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GYPSUM

By Donald W. Olson

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Gypsum is one of the most widely used minerals in the world. In the United States, most gypsum is used to manufacture wallboard for homes, offices, and commercial buildings. An average new American home contains more than 7.31 metric tons (t) of gypsum or, in other terms, more than 6,144 square feet (571 square meters) of gypsum wallboard (Mineral Information Institute, 2001). Worldwide, gypsum is used in portland cement, which is used in concrete for highways, bridges, buildings, and many other structures that are part of our everyday life. Gypsum is also extensively used as a soil conditioner on large tracts of land in suburban areas and in agricultural regions.

After a record setting year in 1999, the gypsum industry in the United States experienced a decline in both production and consumption in 2000. In addition, crude gypsum and wallboard imports declined in 2000. Synthetic gypsum generated by various industrial processes continued to increase as a raw material source for wallboard plants.

During 2000, the U.S. gypsum industry experienced several acquisitions and announcements of construction of new plants and of expansion of production capacity at existing plants. Also in 2000, several older, less efficient manufacturing facilities were closed. In October, U.S. Gypsum Co. closed its old plant in Plaster City, CA, and in December, it closed plants in Gypsum, OH, and Plasterco, VA. In June, U.S. Gypsum opened a plant in Aliquippa, PA; in August, it opened a new plant in Plaster City, CA; and in December, it opened a plant in Rainier, OR. Of these three new plants, the Aliquippa uses synthetic gypsum as its raw material, the Plaster City uses natural gypsum brought in by rail from a nearby quarry, and the Rainier is supplied by natural gypsum imported from Mexico. These openings and closings resulted in a net increase in wallboard production capacity of 1.40 billion square feet (130 million square meters). Georgia-Pacific Corp. closed two of its Grand Rapid, MI, wallboard plants—one in January and the other in November. James Hardie Gypsum acquired the gypsum mining claims of Western Gypsum near St. George, UT, during 2000; this gypsum will supply the Blue Diamond plant at Las Vegas, NV. James Hardie Gypsum also announced plans to build three new joint treatment manufacturing plants; the first of the three started operations in the last quarter of 2000 in Kent, WA. National Gypsum Co. began building the Apollo Beach wallboard plant near Tampa, FL. The plant began operating during the first quarter of 2001; it will have production capacity of 600 million square feet per year (55.8 million square meters per year). This plant supplemented the existing wallboard plant in the Tampa area; both Tampa area plants use synthetic gypsum as their raw material. During the last quarter of 2000, American Gypsum Co. (a subsidiary of Centex Construction Products, Inc.) purchased Republic Gypsum Co. and its wallboard plant in Duke, OK. Lafarge Gypsum completed a new Silver Grove, KY, wallboard plant, near Cincinnati, OH. The new plant will use synthetic gypsum as its raw material. Lafarge has built another wallboard plant in Palatka, FL, which was scheduled to come online in early 2001. This plant also will use synthetic gypsum as its raw material. In

Gypsum in the 20th Century

In 1900, U.S. production of gypsum was about 539,000 metric tons valued at approximately $1.63 million. About 85% of this production was in Iowa, Kansas, Michigan, New York, and Texas. In 1900, the United States also imported about 216,000 tons of gypsum valued at $316,000, mostly from Canada. Of the total domestic gypsum production, about 86% was calcined into plaster of paris, 8% was ground for agricultural use, and the remaining 6% was sold as crude and was probably later ground for agricultural use by consumers. A large quantity of plaster of paris was used in the manufacture of wall plasters for office buildings and for the construction of temporary buildings. In the construction industry in 1900, plasters made from gypsum were beginning to displace softer ones made from lime. Gypsum wallboard was first produced in 1916, and by the 1950s and 1960s, plasters were largely displaced by the use of wallboard.

In 2000, domestic crude gypsum output was approximately 19.5 million metric tons and was valued at $165 million. The top producing States, in descending order, were Oklahoma, Iowa, Michigan, Nevada, Texas, California, and New Mexico, which together accounted for 67% of total output. Overall, 30 companies produced gypsum at 56 mines in 19 States, and 10 companies calcined gypsum at 64 plants in 29 States. In 2000, the United Stated also imported about 9.21 million tons of gypsum valued at $89.3 million, mostly from Canada and Mexico. Synthetic gypsum from coal-fired electric powerplants totaling 4.38 million tons made up 15.3% of the total domestic gypsum supply for the year 2000. Most domestic consumption, which totaled approximately 34 million tons, was accounted for by manufacturers of wallboard and plaster products. More than 3.8 million tons for cement production, approximately 1.9 million tons for agricultural applications, and small amounts of high-purity gypsum for a wide range of such industrial processes as smelting and glassmaking accounted for the remaining production.

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July 2000, British Plasterboard, plc, a London-based firm, acquired the four gypsum wallboard operations of Celotex Corporation located in Cody, WY, Fort Dodge, IA, Jacksonville, FL, and Port Clinton, OH. The new company is called BPB Celotex. BPB Celotex completed a new wallboard plant near Carrollton, KY, with production capacity of 700 million square feet per year (65 million square meters per year). The raw material for the new plant is synthetic gypsum (Sharpe, 2001).

Gypsum industry data for this report are collected by the U.S. Geological Survey (USGS) from semiannual and annual surveys of gypsum operations and are derived from monthly statistics provided by the Gypsum Association in Washington, DC. The 2000 USGS survey, which canvassed 103 gypsum production operations, accounting for almost all domestic output, had a response rate of approximately 93%. The output of producers who did not respond to the survey was estimated from their survey responses in previous years or from other sources familiar with the gypsum industry.

Production

The United States continued to lead the world in gypsum production in 2000, accounting for 18.5% of reported global output. During 2000, domestic output of crude gypsum decreased by 12.8% from that of 1999 to 19.5 million metric tons (Mt) valued at $165 million (table 1).

Crude gypsum was mined in the United States by 30 companies at 56 mines in 19 States. Most of the gypsum, however, was mined by only 4 companies with 25 mines. The top producing States, in descending order, were Oklahoma, Iowa, Michigan, Nevada, Texas, California, New Mexico, Arkansas, Kansas, and Indiana. These States, with 40 mines, each produced more than 1 Mt and together accounted for 84% of total domestic output (table 2).

The U.S. gypsum industry consisted primarily of a few large, vertically integrated companies that mined gypsum and manufactured wallboard, plaster, and other gypsum products. Companies with the most mines were U.S. Gypsum with nine; Georgia-Pacific, seven; National Gypsum, seven; Harrison Gypsum Inc., three; Celotex, two; and James Hardie Gypsum, two. These companies produced almost 71.3% of total U.S. crude gypsum. The 10 largest gypsum mines in the United States accounted for 42.4% of domestic output in 2000. These mines, which were owned by eight companies, had an average output of 829,000 t.

During 2000, gypsum was "calcined" (partially dehydrated by heating) at 64 plants operated by 10 companies in 29 States, principally to produce feedstock for wallboard and plaster plants. The leading States, in descending order, were California, Washington, Texas, Nevada, New York, and Florida. These States, with 24 plants, each produced more than 1.3 Mt of calcined gypsum and together accounted for approximately 43.6% of national output (table 3).

Companies with the most calcining plants were U.S. Gypsum with 21; National Gypsum, 18; Georgia-Pacific, 11; and Celotex, 4. These companies produced 73.7% of national output. The largest 10 calcining plants in the United States accounted for 34.4% of production in 2000. These plants, owned by six companies, had an average output of more than 722,000 metric tons per year.

In addition to mined gypsum production, synthetic gypsum was generated as a byproduct by various industrial processes. The primary source of synthetic gypsum was flue gas desulfurization (FGD) at coal-fired electric powerplants. Smaller amounts of synthetic gypsum were derived from acid neutralization processes. Synthetic gypsum was used as a substitute for mined gypsum, principally for wallboard manufacturing, agricultural purposes, and cement production. In response to USGS surveys, six companies operating in seven States reported that approximately 569,000 t of synthetic gypsum generated by industrial processes at their plants was sold or used for such applications in 2000. In addition to these companies, about 80 domestic coal-fired electric utilities generated approximately 23.3 Mt of synthetic gypsum from their FGD systems during 2000 (American Coal Ash Association, written commun., 2001). Only 4.38 Mt of the synthetic gypsum generated during the year was used, primarily for wallboard production. Use of synthetic gypsum grew by approximately 8.7% during 2000 (Kalyoncu, 2001).

During 2000, 10 companies manufactured gypsum wallboard at 80 plants in the United States. Plant production capacity was expanded by 10.1% to 35.2 billion square feet (3.27 billion square meters) by yearend (Gypsum Association, 2000, 2001). Several new wallboard plants became operational during 2000, providing additional production capacity and replacing older, less efficient manufacturing facilities (Sharpe, 2001). Wallboard shipments during 2000 decreased by 3.18% from those of 1999 to approximately 28.2 billion square feet (2.62 billion square meters). This represents only 80% of the total production capacity (Gypsum Association, 2000, 2001).

Eleven new wallboard plants have been completed or will be completed by yearend 2001. All but one of the new plants will use as their raw material only high-quality, low-cost synthetic gypsum generated by FGD systems operated by electric utilities. Some gypsum companies have expanded or will be expanding synthetic gypsum use at existing wallboard plants as well. U.S. wallboard manufacturing capacity is expected to increase to 37 billion square feet (3.44 billion square meters) by yearend 2002 (Sharpe, 2001). At least a dozen wallboard plants in the United States were already using some synthetic gypsum to augment their feedstock from gypsum mines.

A portion of more than 4 Mt of gypsum waste, generated every year by wallboard manufacturing, wallboard installation, and building demolition, was recycled. The recycled gypsum was used chiefly for agricultural purposes and new wallboard. Other potential markets for recycled gypsum waste are in cement production, as a stucco additive, in sludge drying, in water treatment, in grease absorption, and for marking athletic fields (Turley, 1998; California Integrated Waste Management Board, September 2000, Drywall recycling, accessed August 1, 2001, at URL http://www.ciwmb.ca.gov/condemo/factsheets/drywall.htm).

Consumption

In 2000, the domestic construction industry leveled out, and some sectors declined. In 2000, housing starts declined by 4.38% compared with those of 1999. Apparent domestic consumption (defined as mine output plus reported synthetic used plus imports minus exports plus adjustments for industry stock changes) was about 34 Mt during the year. This was an

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8.11% decline in U.S. gypsum consumption compared with that of 1999. Domestic sources (mining plus an estimated 4.95 Mt of synthetic gypsum) met approximately 73% of domestic consumption requirements; imports satisfied the remaining needs.

Gypsum output is categorized as either calcined or uncalcined (table 4). Calcined gypsum was produced domestically from crude gypsum to manufacture wallboard and plaster products during 2000. Uncalcined gypsum, used for portland cement production and agriculture, accounted for virtually all remaining consumption during the year.

In 2000, 42.7% of the calcined gypsum used to manufacture wallboard was consumed in the production of regular ½-inch wallboard. Fire-resistant wallboard, mobile-home board, water- and moisture-resistant board, lath, veneer base, and sheathing composed most of the balance (table 5). Metropolitan areas in the Atlantic and the Pacific coastal regions were the leading sales areas for gypsum wallboard products.

During 2000, most of the uncalcined gypsum consumed in the United States was used in portland cement production, and the remainder was used primarily in agriculture. Gypsum, which is added to cement to retard its setting time, accounted for about 2% to 5% of cement output (Dutton, 1997). Finely ground gypsum rock was used in agriculture and other industries to neutralize sodic soils, to improve soil permeability, to add nutrients, to stabilize slopes, and to provide catalytic support for maximum fertilizer benefits. Small amounts of high-purity gypsum also were used in a wide range of industrial operations, including the production of glass, paper, foods, and pharmaceuticals.

Prices

In 2000, the average values per metric ton (f.o.b. mine or plant) reported by U.S. producers were $8.44 for crude gypsum and $16.81 for calcined gypsum. The average value for plaster reported by domestic producers during the year was $5.57 per 100 pounds. In 2000, the average value of uncalcined gypsum used in agriculture and in cement production was $12.62 per metric ton.

During 2000, prices for gypsum wallboard generally decreased in response to decreased demand and supply. Prices for regular ½-inch wallboard dropped in 8 of the 20 major U.S. metropolitan areas that were sampled and remained the same in 7 of the 20. During 2000, the price changes from those of 1999 ranged from a decrease of $155 per 1,000 square feet to an increase of $129 per 1,000 square feet. Prices in these 20 U.S. cities ranged from $93 to $280 per 1,000 square feet at yearend (Engineering News-Record, 2000a, b).

Foreign Trade

In 2000, the United States was the world leader in the international trade of gypsum and gypsum products. The Nation imported crude gypsum from 11 countries (table 6), and exported gypsum wallboard to 70 countries and territories. U.S. imports accounted for most of the world's waterborne shipment of crude gypsum (Phillips, 1998). Only a small amount of crude gypsum was exported by the United States (table 7).

Net imports of crude gypsum in 2000, which decreased slightly from those of 1999, accounted for approximately 27% of apparent consumption. Much of this import dependence can be attributed to the lack of adequate domestic gypsum resources near large East Coast wallboard markets. These imports came primarily from Canada and Mexico. The two countries primarily supplied wallboard plants in coastal markets; most imports from Canada went to East Coast plants, and Mexican sources chiefly served the West Coast. Foreign subsidiaries of U.S. gypsum companies produced much of the gypsum that was imported for the wallboard plants. Smaller amounts of imported gypsum were used in portland cement production.

Wallboard exports, totaling about 69 million square feet (6.41 million square meters) and valued at $27 million, were primarily to countries and territories in Asia, Europe, and Latin America. Wallboard imports were about 932 million square feet (86.6 million square meters) valued at $113 million.

World Review

In 2000, 90 countries produced gypsum, 6 of which accounted for 57% of the total world production (table 8). Global gypsum production during 2000 is estimated to be approximately 106 Mt. More than 110 million metric tons per year of synthetic gypsum is generated worldwide (Roskill Information Services Ltd., 2000). The high demand for gypsum in the United States generated by the domestic construction industry was not matched abroad, with the exception of Canada and Mexico, which exported to U.S. markets. The estimate for world production is probably lower than actual because output that is used by the gypsum producers in some countries to make other products onsite was not reported. Additionally, production from small deposits in developing nations was intermittent and in many cases unreported.

As a low-value, high-bulk commodity drawn from deposits widely distributed throughout the world, gypsum tended to be consumed within the many countries that mine it. Less than 20% of the world's crude gypsum production was estimated to enter international trade. Only a few countries, such as Spain and Thailand, were major crude gypsum exporters. Australian exports were expected to grow when the development of a new mine at the world's largest known gypsum deposit on that country's west coast reached full capacity (Dickson, 1999). The proximity of large U.S. wallboard markets also has made Canada and Mexico significant gypsum exporters.

Although use of gypsum wallboard increased worldwide, only industrialized nations, such as the United States, used gypsum primarily for wallboard products. In developing countries (especially in the Middle East and Asia), most gypsum was used in the production of cement or as a plaster product.

Estimated world production capacity for gypsum wallboard in 2000 was at least 60 billion square feet (about 5.6 billion square meters) at more than 250 plants worldwide. About one-half of this capacity was in the United States, and Asia and Western Europe each accounted for about one-fifth. Plans to construct or expand dozens of wallboard plants were underway during the year in many countries throughout the world, including Brazil, Chile, China, Germany, India, Poland, and the United Kingdom (Ambolt, 1999; Dickson, 1999; Mullick, 1999).

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As in the United States, the use of FGD gypsum by other industrialized nations, particularly in Japan and Western Europe, increased (Dickson, 1999).

Outlook

Housing starts for the second quarter of 2001 suggest that U.S. production and consumption may rise slightly or at least match the levels of 2000. Other supply-and-demand indicators, such as construction rates for new office and commercial buildings and the continuing trend to construct larger homes with more rooms, are also evidence that gypsum industry growth in 2001 will be at least level with 2000. As the Transportation Equity Act for the 21st Century (Public Law 105-178, enacted June 9, 1998), authorizing $219 billion for road building and repair through 2003, is further implemented, it will be an important stimulant for the domestic cement industry and for the use of gypsum in cement.

On June 25, 2001, U.S. Gypsum filed voluntary petitions for reorganization under chapter 11 of the U.S. Bankruptcy Code. This action was taken to resolve asbestos-related claims in a fair and equitable manner, while preserving U.S. Gypsum's asset base and ensuring its market position and reputation. During the restructuring period and beyond, U.S. Gypsum's operations will continue without interruption. It is the goal of U.S. Gypsum to address its asbestos liability through chapter 11, to complete its restructuring, and to emerge from chapter 11 as quickly as possible, with a comprehensive and final resolution (USG Corp., July 2001, USG Corporation—Restructuring information, accessed August 12, 2001, at URL http://www.usg.com/special).

During the next several years, the use of mined gypsum may decline significantly in the United States as greater quantities of synthetic gypsum supplant it in wallboard manufacturing. Some actual and planned mine closings already have been attributed to substitution by synthetic gypsum (Gersten, 1999). At least an additional 6 billion square feet (about 560 million square meters) of new wallboard capacity designed for synthetic gypsum feedstock is scheduled to come online by 2002 (Henkels, 1999). This rate of substitution seems likely to accelerate additional mine closings during the next decade.

The domestic gypsum industry is poised for a major change on the supply side. The appearance of very large capacity wallboard plants will trigger a major supply shift. As the U.S. gypsum industry undergoes this change towards large capacity wallboard plants supplied with synthetic gypsum, older, less efficient, and smaller, natural-gypsum-fed plants will find it increasingly difficult to compete. With prices declining, producers will continue to retire older capacity (Harris, 2001).

Industry trends also indicate significant developments abroad in the coming decade. For example, the pace and magnitude of wallboard plant construction in China indicates that China, with more than a billion potential consumers, could become one of the world's leading gypsum wallboard markets. Elsewhere, the extent of wallboard capacity growth in regions of Asia, Europe, and Latin America reveals that wallboard manufacturing is likely to become a more significant application of gypsum worldwide.

References Cited

Ambolt, Lawrence, 1999, The European plasterboard industry: Gypsum, Lime & Building Products, April, p. 10-13.

Dickson, Ted, 1998, Gypsum: Mining Journal Metals and Minerals Annual Review—1998, December, p. 119.

Dutton, John, 1997, Global growth for gypsum: Gypsum, Lime & Building Products, April, 2 p.

Engineering News-Record, 2000a, Construction economics: Engineering News-Record, v. 244, no. 3, January 24, p. 26-27.

———2000b, Construction economics: Engineering News-Record, v. 245, no. 24, December 18, p. 39-40.

Gersten, Alan, 1999, US housing boost for gypsum: Mining Finance, no. 15, June, p. 32.

Gypsum Association, 2000, Annual gypsumboard shipments & industry capacity: Washington, DC, Gypsum Association, January, 1 p.

———2001, Annual gypsumboard shipments & industry capacity: Washington, DC, Gypsum Association, February, 1 p.

Harris, Paul, 2001, Wallboard wonderland—The North American gypsum market: Industrial Minerals, no. 400, January, p. 28-37.

Henkels, P.J., 1999, Synthetic gypsum use in wallboard: Chicago, U.S. Gypsum Co., 5 p.

Kalyoncu, R.S., 2001, Coal combustion products—2000 annual review: U.S. Geological Survey Mineral Industry Surveys, November, 13 p. [Prepared for publication in 2000 U.S. Geological Survey Minerals Yearbook.]

Mineral Information Institute, 2001, Look around...Everything is made from something: Denver, Mineral Information Institute, 1 p. poster.

Mullick, A.K., 1999, Gypsum in India: Gypsum, Lime & Building Products, April, p. 22-29.

Phillips, Keri, 1998, Buoyant global demand: International Bulk Journal, February, p. 55-59.

Roskill Information Services Ltd., 2000, The economics of gypsum and anhydrite (8th ed.): London, Roskill Information Services Ltd., 320 p.

Sharpe, R.D., 2001, Gypsum: Mining Engineering, v. 53, no. 6, June, p. 37-40.

Turley, William, 1998, What's happening in gypsum recycling: C&D Debris Recycling, v. 5, no. 1, January-February, p. 8-12.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Coal Combustion Products. Ch. in Minerals Yearbook, annual.
Gypsum. Ch. in Mineral Commodity Summaries, annual.
Gypsum. Mineral Industry Surveys, monthly.
Gypsum. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Gypsum Association, Washington, DC.
Gypsum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT GYPSUM STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Crude:					
Mined	17,500	18,600	19,000	22,400	19,500
Value	$124,000	$132,000	$132,000	$157,000	$165,000
Imports for consumption	8,050	8,420	8,680	9,340	9,210
Synthetic gypsum sales	2,500	2,700	3,000	5,200	4,950
Calcined					
Produced	17,000	17,200	19,400	22,300	21,000
Value	$287,000	$302,000	$330,000	$381,000	$353,000
Products sold (value)	$2,380,000	$2,550,000	$3,150,000	$3,540,000	$2,860,000
Exports (value)	$81,400	$89,700	$96,300	$93,300	$102,000
Imports for consumption (value)	$196,000	$229,000	$262,000	$465,000	$269,000
World production	104,000 r/	106,000	104,000 r/	106,000 r/	106,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more three significant digits.

TABLE 2
CRUDE GYPSUM MINED IN THE UNITED STATES, BY STATE 1/

	1999			2000		
State	Active mines	Quantity (thousand metric tons)	Value (thousands)	Active mines	Quantity (thousand metric tons)	Value (thousands)
Arizona and New Mexico	6	1,950	$12,840	5	1,440	$7,480
Arkansas, Kansas, Louisiana	5	1,300	12,900	4	2,320	21,000
California, Nevada, Utah	16	5,510	19,100	14	3,390	20,800
Colorado, South Dakota, Wyoming	6	1,160	9,430	6	1,650	13,400
Indiana, New York, Ohio, Virginia	4	2,010	35,200	4	1,970	32,900
Iowa	6	2,570	15,700	6	2,210	17,000
Michigan	4	2,170	15,700	4	1,980	19,800
Oklahoma	8	3,510	20,100	8	2,830	23,500
Texas	6	2,230	15,700	5	1,760	8,980
Total	61	22,400	157,000	56	19,500	165,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 3
CALCINED GYPSUM PRODUCED IN THE UNITED STATES, BY STATE 1/

State	1999 Active plants	1999 Quantity (thousand metric tons)	1999 Value (thousands)	2000 Active plants	2000 Quantity (thousand metric tons)	2000 Value (thousands)
Alabama	1	259	$5,100	1	444	$11,400
Arizona, Colorado, New Mexico, Utah	4	1,730	11,000	4	1,890	13,700
Arkansas, Louisiana, Oklahoma	7	2,410	43,600	6	2,190	35,400
California	6	1,750	30,000	6	1,840	36,500
Maryland, North Carolina, Virginia	5	1,420	33,300	4	1,170	27,700
Florida	3	1,260	27,800	3	1,320	29,600
Georgia	2	782	25,200	1	238	6,040
Illinois, Indiana, Kansas	6	1,600	31,200	6	2,130	34,400
Iowa	4	1,600	26,500	4	1,160	16,400
Massachusetts, New Hampshire, New Jersey	5	1,870	36,600	5	1,230	29,500
Michigan	3	526	16,900	3	366	11,200
Nevada	4	2,830	19,600	4	1,450	13,000
New York	4	1,400	27,700	4	1,340	27,500
Ohio	3	521	10,500	3	444	7,640
Pennsylvania	--	--	--	1	234	5,390
Texas	4	1,480	18,700	5	1,470	21,300
Washington and Wyoming	3	909	17,500	4	2,090	26,300
Total	64	22,300	381,000	64	21,000	353,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
GYPSUM PRODUCTS (MADE FROM DOMESTIC, IMPORTED, AND BYPRODUCT GYPSUM) SOLD OR USED IN THE UNITED STATES, BY USES 1/

(Thousand metric tons and thousand dollars)

Use	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Uncalcined:				
Portland cement	5,730	77,200	3,800	44,100
Agriculture and miscellaneous 2/	4,100	37,700	1,920	28,100
Total	9,830	115,000	5,720	72,200
Calcined:				
Plasters	627	105,000	896	110,000
Prefabricated products 3/	27,000	3,310,000	22,900	2,680,000
Total	27,700	3,420,000	23,800	2,790,000
Grand total	37,500	3,540,000	29,500	2,860,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes byproduct gypsum.
3/ Includes weight of paper, metal, or other materials and some byproduct gypsum.

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TABLE 5
PREFABRICATED GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES 1/

Product	1999 Thousand square feet	1999 Thousand metric tons 2/	1999 Value (thousands)	2000 Thousand square feet	2000 Thousand metric tons 2/	2000 Value (thousands)
Lath:						
3/8 inch	3,960	3	$1,010	3,990	3	$1,040
1/2 inch	(3/)	(3/)	(3/)	(3/)	(3/)	(3/)
Other	323	(3/)	47	(3/)	(3/)	(3/)
Total	4,280	3	1,050	3,990	3	1,040
Veneer base	454,000	463	57,300	431,000	419	49,900
Sheathing	352,000	331	44,900	240,000	214	29,300
Regular gypsumboard:						
3/8 inch	812,000	802	113,000	1,370,000	1,090	116,000
1/2 inch	13,600,000	11,700	1,490,000	12,100,000	9,760	1,170,000
5/8 inch	2,180,000	2,310	184,000	1,160,000	1,250	69,600
1 inch	232,000	249	49,300	168,000	189	39,500
Other 4/	546,000	548	70,000	274,000	240	36,800
Total	17,400,000	15,600	1,910,000	15,100,000	12,500	1,430,000
Type X gypsumboard	7,630,000	7,810	893,000	7,620,000	7,420	792,000
Predecorated wallboard	86,900	87	31,200	99,000	98	29,600
5/16-inch mobile home board	1,530,000	1,450	160,000	1,080,000	816	118,000
Water-and moisture-resistant board	927,000	891	139,000	1,170,000	989	143,000
Other	388,000	374	78,800	436,000	402	84,100
Grand total	28,700,000	27,000	3,310,000	26,100,000	22,900	2,680,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes weight of paper, metal, or other materials.
3/ Less than 1/2 unit.
4/ Includes 1/4-, 7/16-, and 3/4-inch gypsumboard.

TABLE 6
IMPORTS FOR CONSUMPTION OF CRUDE GYPSUM, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999 Quantity	1999 Value	2000 Quantity	2000 Value
Argentina	(2/)	21	--	--
Australia	16	187	16	223
Belgium	2	475	--	--
Canada 3/	6,320	60,300	6,380	66,100
China	(2/)	5	(2/)	2
Dominican Republic	(2/)	14	(2/)	3
Finland	1	948	--	--
Germany	9	1,240	(2/)	13
Japan	(2/)	37	(2/)	64
Mexico	2,260	16,100	2,020	14,600
Morocco	(2/)	13	(2/)	7
South Africa	--	--	(2/)	14
Spain	720	7,260	798	8,110
Taiwan	1	185	--	--
Thailand	17	1,970	--	--
United Kingdom	(2/)	118	(2/)	229
Total	9,340	88,900	9,210	89,300

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes anhydrite.

Source: U.S. Census Bureau.

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TABLE 7
SUMMATION OF U.S. GYPSUM AND GYPSUM PRODUCTS TRADE DATA 1/

(Thousand metric tons and thousand dollars)

Year	Crude 2/		Plasters 3/		Boards 4/		Other	Total
	Quantity	Value	Quantity	Value	Quantity	Value	value 5/	value
Exports:								
1999	112	11,000	588	32,000	52	22,900	27,400	93,300
2000	161	12,600	248	30,200	58	27,100	32,200	102,000
Imports for consumption:								
1999	9,340	88,900	14	3,470	1,710	294,000	79,300	465,000
2000	9,210	89,300	15	3,920	783	113,000	62,600	269,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Import and export data are for "Gypsum, anhydrite," Harmonized Tariff Schedule of the United States (HTS) code 2520.10.0000.
3/ Import and export data are for "Plasters," HTS code 2520.20.0000.
4/ Import and export data are for "Boards, sheets, panels, tiles, and similar articles, not ornamented--faced or reinforced with paper or paperboard only," HTS code 6809.11.0000.
5/ Import and export data are for "Boards, sheets, panels, tiles, and similar articles, not ornamented: Other," HTS code 6809.19.0000, and "Other articles," HTS code 6809.90.0000

Source: U.S. Census Bureau.

TABLE 8
GYPSUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Afghanistan e/	3	3	3	3	3
Algeria e/	250	275	275	275	275
Argentina	633	697	650	571 r/	514
Australia e/	1,800 r/	1,800 r/	1,900 r/	2,500 r/	3,800
Austria e/ 3/	996 4/	1,000	1,000	1,000	1,000
Azerbaijan e/	55	60	60	60	60
Bhutan	55	50	53	54 e/	54
Bolivia	(5/)	(5/)	--	-- e/	--
Bosnia and Herzegovina e/	30	30	30	30	30
Brazil 3/	1,126	1,507 r/	1,632	1,456 r/	1,500
Bulgaria 3/	169	156	183	180	180
Burma	38	38	36	45	48 4/
Canada 3/	8,202	8,628	8,967	9,345 r/	8,548 p/
Chile	520	398	781	886 r/	890
China e/	7,780	9,100	6,800 r/	6,700 r/	6,800
Colombia	522	565	560 e/	560 e/	560
Croatia	86	102	100 e/	100 e/	100
Cuba e/	130	130	130	130	130
Cyprus	94 r/	234 r/	297 r/	182 r/	138 4/
Czech Republic	443	241	222	250	250
Dominican Republic	86	115 r/	80 r/	86 r/	90
Ecuador	2	2	2 e/	2 e/	2
Egypt 3/	2,000 e/	2,423	1,338	1,500 e/	2,000
El Salvador e/	5	6	6	6	6
Eritrea	(5/)	(5/)	(5/)	(5/)	(5/)
Ethiopia e/ 3/	124	120	112 r/	108 r/	108
France e/ 3/	4,550 4/	4,500	4,500	4,500	4,500
Germany (marketable) e/ 3/	3,000	3,000	3,000	2,500	2,500
Greece 3/	546	663	600 e/	600 e/	600 e/
Guatemala e/	28 4/	30	30	30	29
Honduras e/	26	28	30	30	30
Hungary e/ 3/	190	190	180	180	180
India	2,442	2,031	2,192	2,200 e/	2,210
Indonesia	1 e/	--	(5/)	6	5
Iran 6/	8,570	8,900 e/	11,843 r/	10,834 r/	11,000
Iraq e/ 7/	80 r/	85 r/	100 r/	100 r/	80
Ireland	422	477	450	450	450
Israel	161 r/	121 r/	56 r/	50 r/	46

See footnotes at end of table.

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TABLE 8--Continued
GYPSUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000 e/
Italy e/	1,275 4/	1,300	1,300	1,300	1,300
Jamaica	339	264	154	236 r/	240
Japan	5,432	5,371	5,305	5,549 r/	5,600
Jordan	190 e/	194	176	178 r/	175
Kenya e/ 3/	1	1	1	1	1
Laos	113 e/	114	130	135	154
Latvia	64	117	119 r/	97 r/	122 p/
Lebanon e/	3	3	3	3	3
Libya e/	175	125	150	150	175
Luxembourg e/ 3/	(5/)	(5/)	(5/)	(5/)	(5/)
Macedonia e/	25	25	25	25	25
Mali e/	1	1	1	1	1
Mauritania	13	80	100	100 e/	100
Mexico 3/	6,065	5,869	7,045	6,954 r/	7,000
Moldova e/	13 4/	14	14	14	14
Mongolia e/	25	25	25	25 r/	25
Morocco e/	450	450	450	450	450
Namibia	-- e/	-- e/	3	1 r/	1
Nicaragua e/ 3/	13	16 3/	23 3/	23	23
Niger e/	2	2	2	2	2
Nigeria e/	383	300	300	200	300
Pakistan	504	465	244	245	377 3/
Paraguay e/	5	5	5	4	4
Peru	65 r/	64 r/	79 r/	76 r/	52 p/
Poland 3/	1,502 r/	1,618 r/	1,702 r/	1,700 r/ e/	1,700
Portugal e/ 3/	521 3/	500	500	500	500
Romania	91	79	75	75	75
Russia	1,534	559	609 r/	650 r/	700
Saudi Arabia e/	363 3/	365	330	330	350
Serbia and Montenegro	44	32	35	5	15
Sierra Leone e/	(5/)	(5/)	(5/)	(5/)	(5/)
Slovakia 3/	121	116	128	117 r/	120
Slovenia e/	10	10	10	10	10
Somalia e/	1	1	2	2	2
South Africa	341	365	488 r/	514	413 4/
Spain e/ 3/	8,191 4/	8,000	8,000	7,500	7,500
Sudan e/ 3/	5	4 r/	3 r/	4 r/	4
Switzerland e/	300	300	300	300	300
Syria	358 r/	330 r/	290 r/	301 r/	304
Taiwan	3	2	2	(5/) r/	(5/)
Tajikistan e/	30	26	32	35	35
Tanzania 3/	55 r/	46 r/	59 r/	21 r/	21
Thailand	8,934	8,858 r/	4,334	5,005 r/	5,830 4/
Tunisia e/	100	100	100	100	100
Turkey	754	414	352	400	300
Turkmenistan e/	170 3/	85	100	100	100
United Arab Emirates e/	90	90	90	90	90
United Kingdom e/ 3/	2,000	2,000	2,000	1,800	1,500
United States 8/	17,500	18,600	19,000	22,400	19,500 4/
Uruguay	130	943	1,123	1,050 r/	1,000
Venezuela	57	30	80	42 r/	25 4/
Yemen	97 r/ e/	101 r/ e/	102 r/	100 r/	100
Zambia e/ 7/ 9/	11	11	11	11	10
Total	104,000 r/	106,000	104,000 r/	106,000 r/	106,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 13, 2001.

3/ Includes anhydrite.

4/ Reported figure.

5/ Less than 1/2 unit.

6/ Data are for years beginning March 21 of that stated.

7/ For cement production only. Information is insufficient to formulate reliable estimates for output for other uses (plaster, mortar, etc.).

8/ Excludes synthetic gypsum.

9/ Data are for years beginning March 1 of that stated.

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HELIUM

By Norbert Pacheco[1]

Grade-A helium (99.995% or better purity) sales volumes by private industry were 89.6 million cubic meters[2] (3,230 million cubic feet) in the United States in 2000 (table 1). Grade-A helium exports by private producers were 37.0 million cubic meters (1,330 million cubic feet) for total sales of 126.6 million cubic meters (4,564 million cubic feet) of U.S. helium, about an 8% increase from 1999. For 2000, domestic helium sales growth remained relatively stable. However, helium exports increased significantly. The increase in exported helium was mostly due to increased European demand for helium.

Legislation and Government Programs

The Federal Helium Program was established to provide all Federal agencies with current and estimated future helium needs to carry out Government programs authorized and funded by the U.S. Congress. The major Federal helium customers were the National Aeronautics and Space Administration, the U.S. Department of Defense, and the U.S. Department of Energy.

On October 9, 1996, the Helium Privatization Act of 1996 (Public Law 104-273) was signed into law. This legislation directed the Federal Helium Program to discontinue production and sale of refined helium by April 9, 1998. Some of the remaining key components of this legislation and applicable status updates are as follows:

- Dispose of all assets related to helium production, refining, and sales not later than 24 months after helium refinery closing.
  STATUS: A historical review was initiated in June 1999, and reports were completed in August 1999. The phase 1 environmental site assessment was initiated in early 1999, and reports were completed in July 1999. The National Park Service was preparing a historic architectural engineering report on the Amarillo and Exell Plants. Additionally, an application was been filed with the Texas Voluntary Compliance Program for the Landis property, and a contractor was secured for sampling and assessment. Property disposal actions continued.
- Begin selling Federal crude helium reserves in excess of 16.6 million cubic meters (600 million cubic feet) on or before January 1, 2005, and complete sales by January 1, 2015.
  STATUS: Crude helium sales (in kind) for helium that is sold

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[2]All metric helium volumes herein reported are at 101.325 kilopascals absolute (14.696 pounds per square inch absolute) and 15° C (59° F). Helium volumes, reported in parentheses following metric units, are measured in cubic feet at 14.7 pounds per square inch absolute and 70° F—1,000 cubic feet (14.7 pounds per square inch absolute and 70° F) = 27.737 cubic meters (101.325 kilopascals absolute and 15° C) and 1 cubic meter (101.325 kilopascals and 15° C) = 36.053 cubic feet (14.7 pounds per square inch absolute and 70° F).

Helium in the 20th Century

In 1900, helium was essentially unknown. Even though it was first detected during the solar eclipse of August 18, 1868, and it was found to exist in rather large quantities in natural gas wells of the midcontinental United States, commercial recovery of helium did not develop until the onset of World War I. At that time, the British Government became interested in helium as a lifting gas and initiated a research program at the University of Toronto. By 1918, a small experimental plant was operating near Hamilton, Ontario. When the United States entered World War I, the task of establishing a domestic source of helium was given to the U.S. Bureau of Mines. In 1921, the first full scale U.S. helium production plant was completed near Forth Worth, TX, where about 47 million standard cubic feet of helium was produced from the Petrolia Field. It operated until 1929. Because the U.S. Navy was using almost all of the helium produced in the country for the Airship Program, the Bureau of Mines built a new plant near Amarillo, TX, which could produce as much as 25 million cubic feet per year of helium. Later, the Bureau of Mines built the Exell plant, also in Texas, which eventually became its last operating plant. These two plants extracted helium from natural gas produced from the Government's Cliffside Field. Later, the Cliffside Field reservoir (also known as the Bush Dome) would become the only helium storage reservoir in the world.

In the 1950s, optimism about future markets for helium developed, and helium began to be considered as a resource during the cold war. Widespread use led to the Helium Act of 1960, which created the Helium Conservation Program, allowing for private helium production. As a result, five new private helium extraction plants were built over the next several years. From 1963 to 1973, the U.S. Government purchased helium from the private producers and stored it in Bush Dome. The helium industry continued to grow as more uses for helium were discovered. By 1996, 14 private companies owned a total of 20 helium plants, and U.S. helium consumption had grown to 2.6 billion standard cubic feet per year.

In 2000, the United States still led the world in helium production, accounting for about 80% of world output. Twelve U.S. private companies owned and operated 21 domestic helium production plants. U.S. helium consumption had grown to over 3.4 billion standard cubic feet per year, and demand for helium continued to grow worldwide. By then, helium uses included cryogenics, pressurizing and purging, welding, atmospheric control, leak detection, breathing mixtures, lifting, and medical applications.

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to Federal agencies and their contractors by private companies began in January 1998. Open-market sales of crude helium were reviewed in a legislatively mandated study conducted by the National Academy of Sciences (NAS) concerning the impact on national, scientific, and military interests. The NAS study was completed in March 2000. Helium regulations, however, are being developed and, once in place, will be used to guide open-market sales of the crude helium.

- Continue operation of the helium storage field system, which includes the storage field and the crude helium pipeline used for storage and distribution of Government-owned and privately owned crude helium.
- Continue collection of helium royalties and fees from sales of helium extracted from gas produced from Federal lands.
- Continue helium resource evaluation and reserve tracking to monitor helium availability for essential Government programs.
- Complete land transfer to the Texas Plains Girl Scouts Council.
  STATUS: Historical and archeological reviews and environmental assessments were being carried out and were expected to be completed by August 2001.

Production

In 2000, 12 companies operated 21 privately owned domestic helium plants, 15 of which extracted helium from natural gas (table 2; figures 1, 2). All but two extraction plants used cryogenic extraction processes. The total sales of U.S. produced helium increased by 12.0% compared with that of 1999. All natural gas processed for helium recovery came from gasfields in Colorado, Kansas, Oklahoma, Texas, Utah, and Wyoming. During 2000, 11 private plants purified helium by using pressure swing adsorption technology. Nine privately owned plants that produced grade-A helium also liquefied helium. The plant operators and plant locations are listed in table 2.

Domestic production data for helium were developed by the Bureau of Land Management (BLM) from records of its own operations, as well as from its own high-purity helium survey, a single voluntary canvass of private U.S. operations. Of the nine operations to which a survey request was sent, 100% responded. Those data plus data from BLM operations represent 100% of the total helium sales and recovery data listed in table 3.

Domestic measured helium reserves and indicated helium resources as of January 1, 2000, were estimated to be 8.9 billion cubic meters (323 billion cubic feet). The resources include measured helium reserves estimated to be 4.1 billion cubic meters (147 billion cubic feet) in natural gas from which helium is being extracted. The measured reserves included nearly 951 million cubic meters (34.3 billion cubic feet) stored by the BLM in the helium storage conservation system. Measured helium reserves from indicated resources of natural gas with helium content greater than 0.05% are estimated to be 1.8 billion cubic meters (65 billion cubic feet). Indicated helium resources, a category of reserves slightly less certain than measured reserves, in natural gas with less than 0.3% helium were estimated to be 3.1 billion cubic meters (111 billion cubic feet). The majority of these indicated reserves were derived from the Potential Gas Committee designation of unconfirmed/probable reserves (Curtis, 2000, p. 2-3). Approximately 2.6 billion cubic meters (94 billion cubic feet), or 98% of the domestic helium reserves that are under Federal ownership from which helium is being extracted, is located in the Riley Ridge area in Wyoming and the Cliffside Field in Texas.

The changes in how the helium reserves have been reported above are meant to provide the reader a better view of the helium reserves from which helium is being extracted. The 4.1 billion cubic meters (147 billion cubic feet) is estimated helium reserves that can be extracted from natural gas production over the expected life of gasfields from which gas is currently being produced. The 1.8 billion cubic meters (65 billion cubic feet) is estimated measured helium reserves in gasfields, from some of which helium could be extracted in the future. The 3.1 billion cubic meters (111 billion cubic feet) is indicated helium resources in probable/unconfirmed natural gas resources from which helium is not likely to be extracted.

Most of the domestic helium resources are in the midcontinent and the Rocky Mountain regions of the United States. The measured helium reserves are in approximately 102 gasfields in 11 States. About 97% of these reserves are contained in the Hugoton Field in Oklahoma, Kansas, and Texas; the Panoma Field in Kansas; the Keyes Field in Oklahoma; the Panhandle West and the Cliffside Fields in Texas; and the Riley Ridge area in Wyoming. During 2000, the BLM analyzed 506 natural gas samples from 4 States in conjunction with its program to survey and identify possible new sources of helium.

Consumption

In 2000, private industry supplied 100% of the domestic demand. The major domestic end uses of helium were cryogenics (24.4%), pressurizing and purging (19.9%), welding (18.2%), and controlled atmospheres (16.0%). Minor uses included leak detection (5.6%), synthetic breathing mixtures (3.1%), and chromatography/lifting gas/heat transfer (total 12.8%) (figure 3). Cryogenics, specifically magnetic resonance imaging applications, dominated liquid helium use. Estimated 2000 domestic consumption by end use was based on a 1996 end-use survey conducted by BLM Helium Operations to determine the trends in helium usage.

New regulations, effective November 23, 1998, concerning in-kind crude helium sales were published in 43 CFR chapter II, part 3195. These regulations require that helium refiners selling to Federal agencies and their contractors must buy an equivalent amount of crude helium from the BLM. Such sales are referred to as "in-kind crude helium sales." In 2000, in-kind crude helium sales were 6.4 million cubic meters (231 million cubic feet) and were made by nine companies through contracts with the BLM.

Stocks

The volume of helium stored in the BLM helium conservation storage system, including the conservation pipeline network and the Cliffside Field, totaled 952 million cubic meters (34.3 billion cubic feet) on December 31, 2000. The storage system contained crude helium purchased under contract by the BLM from 1962 to 1973 and privately owned helium extracted by industry from natural-gas-supplying fuel markets and stored under contract. This and privately owned helium is returned to

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the owners as needed for purification to supply private demand. During 2000, 23.3 million cubic meters (840 million cubic feet of private helium was delivered to the BLM's helium conservation system, and 51.9 million cubic meters (1,870 million cubic feet) was withdrawn for a net decrease of 28.6 million cubic meters (1,030 million cubic feet) of private helium in storage (table 4).

Transportation

Private producers and distributors shipped helium predominantly as a liquid in semitrailers. These semitrailers delivered the liquid helium to distribution centers where some of it was gasified and compressed into trailers and small cylinders for delivery to end users. The remaining liquid helium was sold as bulk liquid or repackaged in dewars of various sizes for delivery.

Prices

The price charged for crude helium to private companies for in-kind crude helium sales was $1.785 per cubic meter ($49.50 per thousand cubic feet) for fiscal year 2000.

Foreign Trade

In 2000, exports of grade-A helium increased to 37.0 million cubic meters (1.33 billion cubic feet) (table 1). Helium exports increased by 38.1% compared with those of 1999 and accounted for 29.2% of the U.S.-produced helium sales; private industry supplied all U.S. helium exports. The large increase in helium exports is attributed to increased European demand for helium. About 55% of the U.S. helium exports went to Asia, with Japan receiving about 71% of those exports. About 24% of the exported helium was shipped to Europe. Collectively, Belgium, France, Germany, and the United Kingdom received 94% of the helium exported to Europe. Other exports were as follows: Canada and Mexico, 8%; South America, 5%; Australia-New Zealand, 5%; the Middle East, 2%; Africa, Central America, and the Caribbean, less than 1% each. Import tariffs on helium established on January 1, 1998, remained at the 3.7% rate for normal-trade-relations nations and at the 25% rate for non-normal-trade-relations nations.

World Review

Excluding the United States, world production capacity of helium was estimated to be 29 million cubic meters (1.05 billion cubic feet). All known helium produced outside the United States was extracted in Algeria, Poland, and Russia (table 5).

Outlook

The total market for U.S.-produced helium increased by 8.2% compared with that of 1999. From 1995 to 2000, the market growth rate was about 5.7%.

Expansion of the Asian helium market over the next 2 years is expected to moderate owing to the uncertain economic conditions in that region of the world. Competition from foreign helium producers will provide continued uncertainty to the strength of the U.S. exports to the global helium market. Helium sales in the private sector are expected to continue at a moderate growth rate of 5% during the next 3 years. Use of high-temperature superconductor materials in electric motor windings and increased fiber optics demands are expected to increase helium demand.

Reference Cited

Curtis, J.B., 2000, National resource estimates for 2000—A report of the Potential Gas Committee: Golden, CO, Colorado School of Mines, 346 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Helium. Ch. in Mineral Commodity Summaries, annual.
Helium. Ch. in Minerals Yearbook, annual.
Helium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Analyses of Natural Gases, 1917-85. U.S. Bureau of Mines Information Circular 9129, 1987.
Analyses of Natural Gases, 1986-90. U.S. Bureau of Mines Information Circular 9301, 1991.
Analyses of Natural Gases, 1991. U.S. Bureau of Mines Information Circular 9318, 1992.
Analyses of Natural Gases, 1992. U.S. Bureau of Mines Information Circular 9356, 1993.
Analyses of Natural Gases, 1993. U.S. Bureau of Mines Information Circular 9400, 1994.
Analyses of Natural Gases, 1996-97. Bureau of Land Management Technical Note 404, 1998.
Helium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Helium Resources of the United States, 1991. U.S. Bureau of Mines Information Circular 9342, 1993.
Helium Resources of the United States, 1997. Bureau of Land Management Technical Note 403, 1998.

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TABLE 1
TOTAL SALES OF GRADE-A HELIUM PRODUCED IN THE UNITED STATES 1/

(Million cubic meters)

Year	Volume		
	Domestic sales	Exports 2/	Total sales
1996	71.9	22.8	94.7
1997	77.4	29.5	107
1998	84.2	27.8	112
1999	89.8	26.8	117
2000	89.6	37.0	127

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Source: U.S. Census Bureau.

TABLE 2
OWNERSHIP AND LOCATION OF HELIUM EXTRACTION PLANTS IN THE UNITED STATES IN 2000

Category and owner or operator	Location	Product purity
Government owned, Bureau of Land Management 1/	Masterson, TX	Grade-A helium 2/
Private industry:		
Air Products and Chemicals Inc.	Hansford County, TX	Do. 2/
Do.	Liberal, KS	Do. 2/
BOC Gases, Inc.	Otis, KS	Do. 2/
BP p.l.c.	Sunray, TX	Crude helium
Do.	Ulysses, KS	Do.
CIG Co. (a subsidiary of El Paso Corp.)	Keyes, OK	Grade-A helium 2/
Do.	Lakin, KS	Crude helium
Duke Energy Field Services	Cheyenne Wells, CO	Crude and grade-A helium 2/
Do.	Hansford County, TX	Crude helium
Do.	Liberal, KS	Do.
Do.	Moore County, TX	Do.
Exxon Co., U.S.A.	Shute Creek, WY	Crude and grade-A helium 2/
Nitrotec Energy Corp. 3/	Cheyenne Wells, CO	Grade-A helium
Do.	Chillicothe, TX	Do.
ONEOK, Inc.	Bushton, KS	Crude helium
Do. 4/	Scott City, KS	Do.
Pioneer Natural Resources Co.	Fain, TX	Do.
Do.	Satanta, KS	Do.
Praxair, Inc.	Bushton, KS	Grade-A helium 2/
Do.	Ulysses, KS	Do. 2/
Tom Brown Inc.	Moab, UT	Crude and grade-A helium 2/
Williams Field Services Co.	Baker, OK	Crude helium

1/ Stopped production in March 1998.
2/ Including liquefaction.
3/ Stopped production in late 1999.
4/ Output is piped to Ulysses, KS, for purification.

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TABLE 3
HELIUM RECOVERY IN THE UNITED STATES 1/ 2/

(Thousand cubic meters)

	1996	1997	1998	1999	2000
Crude helium:					
Bureau of Land Management (BLM) total storage	(7,230)	(6,130)	(100)	--	--
Private industry:					
Stored by BLM	36,700	36,700	33,000	32,000	23,300
Withdrawn	(21,200)	(21,300)	(31,400)	(35,100)	(51,900)
Total private industry storage	15,500	15,400	1,600	(3,100)	(28,600)
Total crude helium	8,270	9,270	1,500	(3,100)	(28,600)
Grade-A helium:					
BLM sold	6,060	5,260	2,000	--	--
Private industry sold	88,600	102,000	110,000	117,000	126,600
Total sold	94,700	107,000	112,000	117,000	126,600
Total stored	8,270	9,270	1,500	(3,100)	(28,600)
Grand total recovery	103,000	116,000	114,000	114,000	98,000

-- Zero.
1/ Negative numbers are enclosed in parentheses to denote net withdrawal from the BLM's underground storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
SUMMARY OF BUREAU OF LAND MANAGEMENT HELIUM CONSERVATION STORAGE SYSTEM OPERATIONS 1/ 2/ 3/

(Thousand cubic meters)

	1998	1999	2000
Helium in conservation storage system on January 1:			
Stored under BLM conservation program 4/	852,000	847,000	841,000
Stored for private producers under contract	131,000	135,000	138,000
Total 4/	983,000	983,000	979,000
Input to system:			
Net deliveries from BLM plants	(100)	--	--
Stored for private producers under contract	33,000	32,000	23,300
Total 4/	33,000	32,000	23,300
Redelivery of helium stored for private producers under contract	(31,500)	(35,100)	(51,900)
Net addition to system 4/	1,500	(3,100)	(28,600)
Helium in conservation storage system on December 31:			
Stored under BLM conservation program 4/	847,000	841,000	836,000
Stored for private producers under contract	135,000	138,000	116,000
Total 4/	983,000	979,000	952,000

-- Zero.
1/ Crude helium is injected into or withdrawn from the BLM's underground storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Numbers in parentheses indicate net withdrawal from storage.
4/ Net additions to system do not include in-kind crude sales or transfers. However, totals do include crude sales and transfers.

TABLE 5
WORLD GRADE-A HELIUM PRODUCTION
ANNUAL CAPACITY, DECEMBER 31, 2000

(Million cubic meters)

	Capacity
United States 1/	145
Rest of the world e/	29
Total e/	174

e/ Estimated.
1/ Includes plants on standby as well as operating plants.

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FIGURE 1
MAJOR U.S. HELIUM-BEARING NATURAL GAS FIELDS

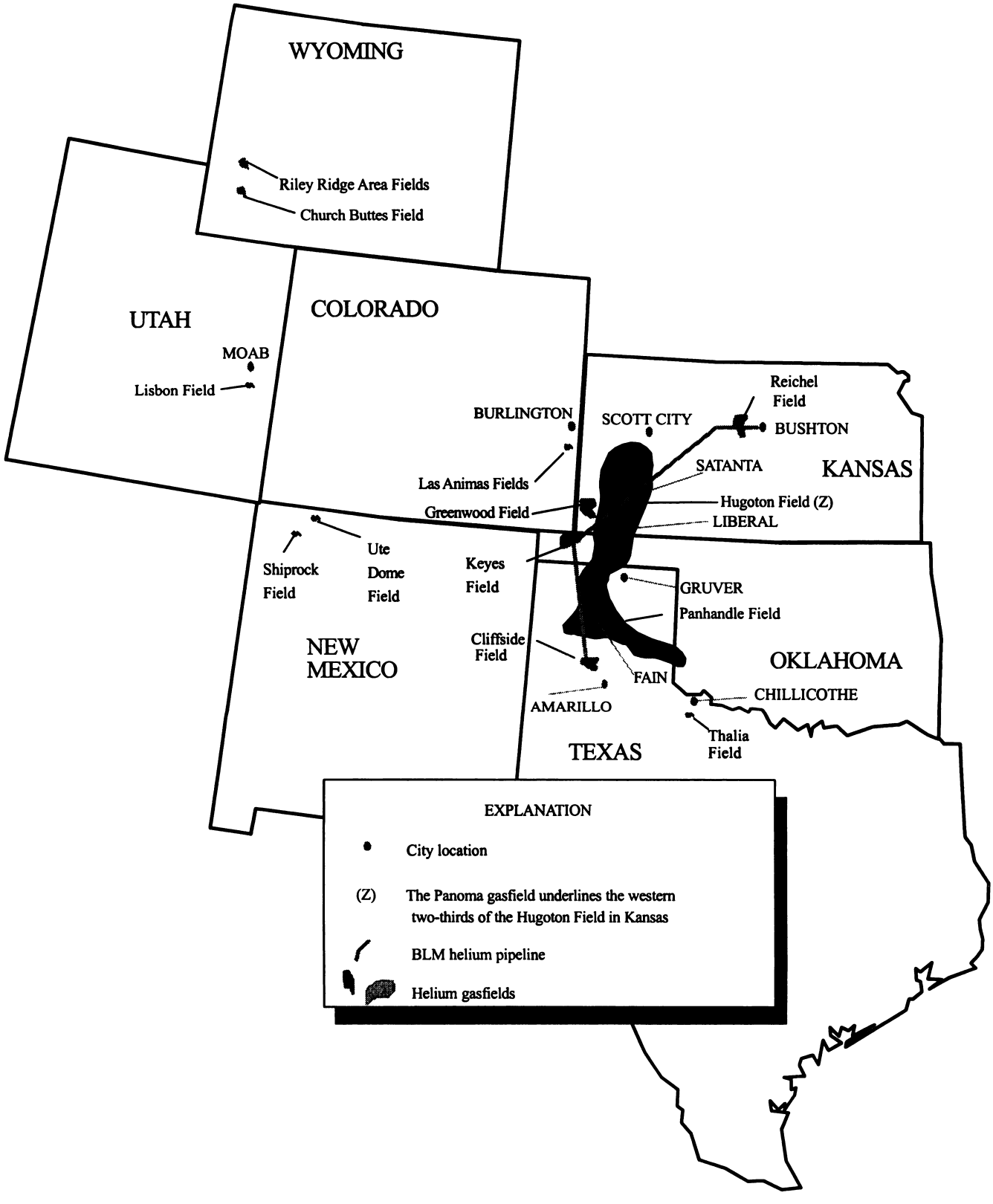

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FIGURE 2
HELIUM RECOVERY IN THE UNITED STATES

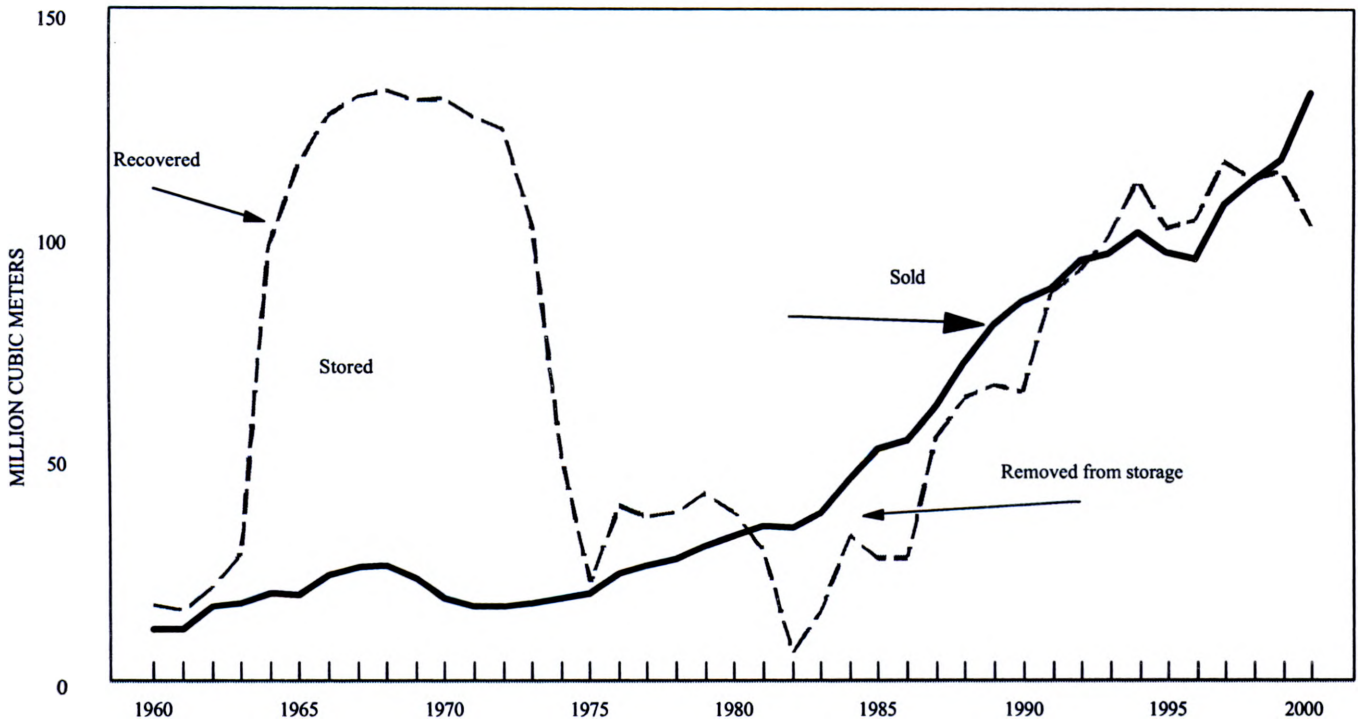
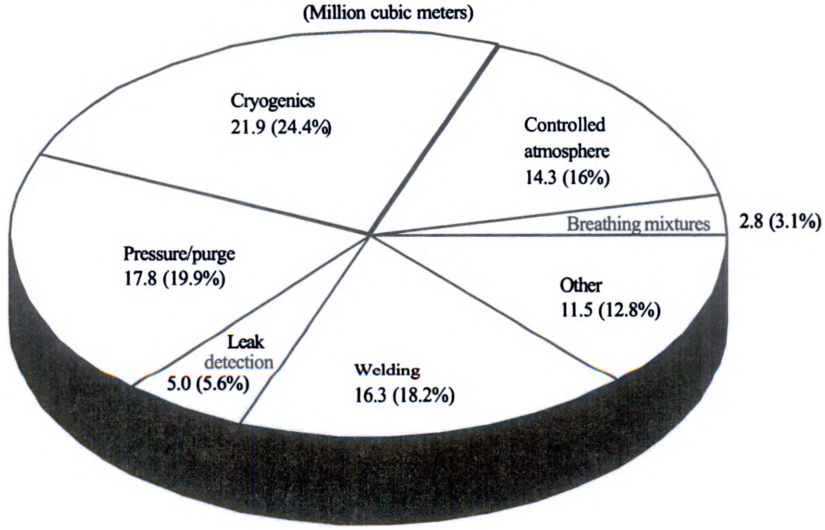


FIGURE 3
ESTIMATED HELIUM CONSUMPTION, BY END USE,
IN THE UNITED STATES IN 2000
(Million cubic meters)



Estimated total helium used
(89.6 million cubic meters)

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INDIUM

By Robert D. Brown, Jr.

Domestic survey data and table were prepared by Carolyn F. Crews, statistical assistant.

Indium production in the United States during 2000 was confined to the upgrading of imported metal and the recycling of scrap. Two refiners, one each in New York and Rhode Island, were the major producers of indium metal and indium products in 2000. A number of smaller firms also produced high-purity indium alloys, compounds, solders, indium-tin oxide (ITO) coatings, and related products.

Domestic consumption was estimated by the U.S. Geological Survey to have increased moderately to about 55 metric tons (t) in 2000. Estimated uses were about the same as those in 1999, with stable consumption in all sectors except semiconductors, where there was a moderate increase. By sector, estimated consumption in 2000 was: coatings, 49%; solder and alloys, 33%; electrical components and semiconductors, 14%; and other uses, 4%. The value of primary indium consumed in the United States in 2000 was $10.3 million at an average producer price of $5.84 per troy ounce, calculated from prices published in Platt's Metals Week.

World consumption increased slightly in 2000. World refinery production was estimated at 220 t, a 2.3% increase compared with the 215 t (revised) produced in 1999. The six major producing countries were Belgium, Canada, China, France, Japan, and Russia. The recycling of indium, which became significant for the first time in 1996, was not significant domestically in 2000. However, recycling remains important in Japan (McCullouch, 2000). The increase in world consumption despite greater efficiency in the manufacture of ITO coatings with thin film transistor technology was due to increased demand for display devices and an increase in the production of indium phosphide, a semiconductor. Prices remained low despite strong demand, mostly owing to plentiful low-priced supplies from China (Mining Journal, 2000a).

World reserves, which are based on estimated indium content of zinc reserves, are sufficient to meet anticipated demand beyond the first decade of this century. Canada has greater resources of indium than any other country—about 27% of world reserves totaling 2,600 t. The United States holds about 12% of world reserves.

Legislation and Government Programs

The original National Defense Stockpile (NDS) goal for indium, set in 1989, was 41,990 kilograms (kg). In 1992, when the first purchase of indium was made for the stockpile, the goal was reduced to 7,740 kg. By 1996, as for many other commodities, the Annual Materials Plan for the NDS called for the elimination of indium from the stockpile. No sales were made in 1996, but stockpile disposals of indium amounted to 1,118 kg (35,956 troy ounces) in 1997, and (the last) 443 kg (14,248 troy ounces) in 1998. From that point on, the stockpile was depleted and the United States became completely dependent on imports for primary indium.

Production

U.S. production of primary indium in 2000 consisted of upgrading lower-grade and standard-grade indium (99.97% and 99.99%) into higher purity metal. Indium can be refined to purities up to 99.99999%. All of the indium to be upgraded was imported. Secondary production was mainly from new (unused, preconsumer) scrap and certain types of old (used, postconsumer) scrap. Nevertheless, only a small amount of indium was recycled domestically. Indium was produced in various forms, such as ingot, foil, powder, ribbon, shot, and wire.

Consumption

Domestic consumption in 2000 was estimated at about 55 t, a moderate increase from the 1999 level. Consumption in the various end uses held nearly steady, but semiconductor use increased. Thin-film coatings on glass, which included indium oxide and indium-tin-oxide, constituted almost one-half of total domestic indium use in 2000. The coatings, produced by sputtering the material onto a glass substrate, have been the largest area of research, development, and growth for indium in the past several years.

There are two kinds of indium-containing coatings—electrically conductive coatings and infrared-reflective coatings. Electrically conductive coatings, the more commercially significant group, are used primarily in liquid crystal displays (LCD) for watches, television screens, portable computer screens, and video monitors. They are also used to defog aircraft and locomotive windshields and to keep glass doors on commercial refrigerators and freezers frost-free. In addition, infrared-reflecting indium coatings on window glass limit the transfer of radiant heat through the glass, helping to make the heating and cooling of buildings more energy efficient.

About 33% of the indium consumed was used as an addition to combinations of bismuth, cadmium, lead, and tin to form low-melting-point alloys. These alloys are used in such applications as electrical fuses, fusible links, or as gripping material for the grinding of optical glass. Indium is used as a strengthening agent for lead solders and also as the base material for many low-melting-point solders. Indium-based solders have a number of advantages over ordinary solders: lower melting points, flexibility over a greater temperature range, and negligible leaching of gold components from electronic assemblies. Lead-free solders have been developed starting with indium-based alloys.

Indium is used in alkaline batteries to prevent the buildup of hydrogen gas in the sealed battery casing. These batteries are available in popular small consumer sizes, and together with semiconductors and other electronic uses, accounted for about

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14% of the indium consumed domestically.

Prices

The domestic producer price as reported by Platt's Metals Week for 99.97%- to 99.99%-pure indium decreased from $6.22 per troy ounce at the beginning of 2000 to $4.58 per troy ounce at the end of the year; prices for higher grades of metal were not published. The price decline was a reflection of the world supply and demand situation. The average producer price was $6.22 per troy ounce at the beginning of the year. It held steady until early May, when it was lowered to $5.83 per troy ounce. The price fell again in October, first reaching $5.20 and then $4.58 per troy ounce (Platt's Metals Week, 2000b). The average indium price for the year was $5.84 per troy ounce.

The price for indium increased markedly in 1995 and then decreased just as markedly in 1996. Only modest fluctuations occurred in 1997. The price was nearly constant in 1998 and began a slow decline in 1999 which continued in 2000. The falling prices in 2000 were caused by good supply rather than poor demand. Chinese producers continued to sell at lower and lower prices, especially during the second half of the year. Higher purity indium is required for ITO, and Western indium producers were able to obtain a premium for their metal, creating a two-tier market (Platt's Metals Week, 2000c), but plentiful low-priced Chinese offers pulled down world prices (Platt's Metals Week, 2000e). One negative on the demand side was that demand was lower than expected from new Taiwanese consumers, manufacturing LCDs (Metal Bulletin, 2000a).

Trade

Imports decreased 10% by weight and 33% in value. For the first time China replaced Canada as the top supplier. These two provided 68% of the total. Next, in order of importance, were France, Russia, Peru, and Japan. Data on U.S. exports of indium were unavailable, but total exports were estimated at about 15 t.

World Review

Asia.—The world indium market in 2000 was dominated by a more than adequate supply from China. Japan remained the world's largest consumer of indium, with three-fourths of it going for ITO coatings. Low-priced indium was so readily available from China that prices remained low despite strong demand, especially in Japan (Mining Journal, 2000b, c).

Canada.—An interruption of indium production occurred at the Kidd Creek, Ontario, plant of Falconbridge Ltd. at the beginning of the year. A runout at a copper furnace combined with regular maintenance stopped production for 6 weeks, beginning in December 1999. Indium production was only reduced slightly (Mining Journal, 2000b).

China.—Chinese indium producers began to control sales in an attempt to prevent indium prices from falling further. Since indium is a byproduct of zinc, which must be produced continuously, the actual cost of indium production is low. Therefore, producers allow their stocks to increase rather than choose to curtail production, even if this creates a greater oversupply (Platt's Metals Week, 2000a).

Japan.—Indium demand reached a record 335 t in 2000 in Japan, with slightly more than one-half of the material coming from recycled scrap. ITO production increased 26% by weight over 1999 (Roskill's Letter from Japan, 2001b). Indium phosphide production increased 57% in value over 1999 (Roskill's Letter from Japan, 2001a).

Showa Denko K.K., already the world's leading producer of indium phosphide wafers using the metal-organic chemical deposition process, invested $29 million to triple its capacity at its Chichibu plant, northwest of Tokyo. Production of both indium phosphide epitaxial wafers and indium phosphide mirror wafers was expected to triple by mid-2001 (Furukawa, 2000a).

Owing to the booming electronics sector in Japan, Sumitomo Electric Industries Ltd. announced plans to expand its output of indium (and gallium and zinc) at its Itami plant, northwest of Tokyo. The materials produced are for compound semiconductors used in products like mobile phones (Platt's Metals Week, 2000d). Sumitomo also announced plans to establish new production facilities for indium phosphide and other semiconductors in the United States. The operation will produce gallium arsenide as well as indium phosphide (Furukawa, 2000b).

Taiwan.—Mitsui Mining & Smelting Co. Ltd. of Japan plans to build an ITO sputtering target plant in Taiwan. Taiwan is becoming one of the world's largest producers of the targets. The plant, a wholly owned subsidiary of Mitsui, is to be named the Taiwan Target Company and will be located near Taichung (Metal Bulletin, 2000b).

Current Research and Technology

In 2000, the growth rate for the thin film transistor LCD, which requires only one-third as much indium per unit as the supertwisted nematic (STN) LCD, was four times higher than that for the STN LCD. Since more than one-half of the world's indium consumption is for ITO coatings, the conversion to a more efficient technology has the same effect as would an increase in indium reserves.

Demand for indium phosphide wafers increased in 2000 for use in dense wavelength division multiplexing (DWDM) systems. These DWDM systems greatly increase the amount of information that can be transmitted on the Internet through optical glass fibers (Furukawa, 2000a).

At the Sandia National Laboratory of the U.S. Department of Energy, scientists researched uses and properties of indium gallium arsenic nitride semiconductor alloys. The addition of nitrogen to this system reduces gallium arsenide's bandgap energy requirement by one-third. The new material has potential for use in fiber optic lasers and communication satellites. As a part of a solar cell to provide power for space systems, this material could provide twice the efficiency of a standard silicon solar cell—up to 40%. A solar collecting package using this material would be smaller and lighter, providing increased payloads and cheaper launches. The utilization of this system for lasers makes it possible to adjust the gallium arsenide bandgap and provide a laser needed for short-distance fiber optics systems with greater manufacturing efficiency (Allan, 2000).

A new solar cell, based on a copper/indium/selenium compound has been developed in Germany. Cis-Solartechnik, GmbH, partly owned by Norddeutsche Affinerie AG, will continue development work on the new product, which is made

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mostly by deposition through galvanic processes onto a flexible copper strip. The new cell, with greater than 10% efficiency, is light in weight and extremely tough (American Metal Market, 2000).

Outlook

Consumption of indium is expected to increase throughout the next decade, especially for LCDs, high-definition television, semiconductor materials, batteries, and low-temperature solders for military and electronic applications. The main driving force for this increase will continue to be Japanese production of LCDs using ITO and the production of telecommunications-use lasers and photo-diodes and other optic telecommunication systems using indium phosphide (Furukawa, 2000b).

Roskill predicted a world demand of 250 t by 2005 (Roskill Information Services, 1999). Japanese plus U.S. consumption of primary indium reached 225 t in 2000, mostly for ITO. Demand for indium needed for replacement nuclear control rods should remain steady, and that for fusible alloys and solders is likely to increase. If the price of indium rises sufficiently, recycling of the metal could increase in the United States and would tend to limit upward movements in price as long as a supply of appropriate scrap existed. Stocks of scrap increase when little recycling is occurring—as in recent years. World reserves, together with increases in production capacity (achieved through new plants and increased yields in primary recovery and improvements in manufacturing and recycling technology) are expected to be sufficient to meet the demand for indium beyond 2010.

However, other possible economic scenarios could diminish optimistic forecasts. For example, any slowdown of sales and profit growth in the telecommunications industry, which has been forecast by some industry observers, could significantly decrease indium demand (Berenson, 2001; Romero, 2001).

References Cited

Allan, Roger, 2000, Indium gallium arsenide looks promising as very efficient photo voltaic source: Electronic Design, v. 48, no. 8, April 17, p. 25-28.

American Metal Market, 2000, German company in copper project: American Metal Market, v. 108, no. 201, October 18, p. 6.

Berenson, Alex, 2001, Pain may not be over for telecommunications equipment: New York Times, June 18, p. C1, 3.

Furukawa, Tsukasa, 2000a, Showa to boast indium wafer output: American Metal Market, v. 108, no. 169, August 31, p. 8.

———2000b, Sumitomo makes gallium, indium push: American Metal Market, v. 108, no. 220, November 14, p. 8.

McCulloch, Russ, 2000, Indium displays a bright future: Metal Bulletin Monthly, no. 357, September, p. 55-57.

Metal Bulletin, 2000a, Germanium sees more interest while indium still languishes: Metal Bulletin, no. 8492, July 13, p. 9.

———2000b, Mitsui Mining & Smelting to build ITO plant: Metal Bulletin, no. 8502, August 31, p. 9.

Mining Journal, 2000a, Minor metals in October: Mining Journal, v. 335, no. 8607, November 3, p. 361.

———2000b, Minor metals wake up: Mining Journal, v. 334, no. 8572, March 3, p. 181.

———2000c, Minor's march halted: Mining Journal, v. 334, no. 8577, April 7, p. 273.

Platt's Metals Week, 2000a, Chinese indium producers control sales on weak prices: Platt's Metals Week, v. 71, no. 45, November 6, p. 11.

———2000b, Indium Corp. cuts its price to $135/kg: Platt's Metals Week, v. 71, no. 42, October 16, p. 15.

———2000c, Producers, dealers disagree on indium market: Platt's Metals Week, v. 71, no. 40, October 2, p. 3.

———2000d, Sumitomo to expand rare metal facilities: Platt's Metals Week, v. 71, no. 35, August 28, p. 15.

———2000e, Supply surplus sends indium prices tumbling: Platt's Metals Week, v. 71, no. 44, October 30, p. 15.

Romero, Simon, 2001, Once-bright future of optical fiber dims: New York Times, June 18, p. A1, 17.

Roskill Information Services, 1999, Economics of Indium: Roskill Information Services, London, 113 p.

Roskill's Letter from Japan, 2001a, Indium-Prices fall to a record low level: Roskill's Letter from Japan, no. 293, January, p. 5, 6.

———2001b, Indium-Record Japanese demand in 2000: Roskill's Letter from Japan, no. 296, April, p. 10, 11.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Indium. Ch. in Mineral Commodity Summaries, annual.
Indium. Ch. in Minerals Yearbook, annual.
Gallium, Germanium, and Indium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Indium. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDIUM, BY CLASS AND COUNTRY 1/

Class and country	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)
Unwrought and waste and scrap:				
Belgium	1,850	$323	158	$33
Canada	31,800	6,390	19,800	2,600
China	28,700	4,690	26,900	3,310
France	5,780	1,230	10,800	1,680
Germany	80	12	163	19
Hong Kong	396	54	40	3
Japan	634	226	2,230	487
Kazakhstan	--	--	229	21
Peru	2,100	382	2,570	333
Russia	5,100	984	5,120	787
Singapore	30	3	--	--
Switzerland	500	93	1,000	140
United Kingdom	410	137	507	208
Total	77,400	14,500	69,400	9,620

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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IODINE

By Phyllis A. Lyday

Domestic survey data and tables were prepared by John G. Durand, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Three producers of crude iodine supplied about 27% of domestic demand (table 1). Domestic and imported iodine was consumed in intermediate products prior to being sold to consumers (table 2). Iodine and derivatives find principal uses in pharmaceutical and medical applications, sanitation or disinfectants, animal feed, catalysts, inks, colorants, photographic equipment, and stabilizers. Published prices for crude iodine were unchanged from 1999 (table 3). Imports of crude iodine decreased by 7%, and imports of potassium iodide increased by 65% (table 4). End uses for domestic consumption in 2000 were reported in potassium iodide, which decreased by 26%, and sodium iodide, which decreased by 27%. Exports of crude iodine and potassium iodide were at 1999 levels during 2000 (table 5). Because some exports and imports are in product categories rather than crude products, net imports are not clearly distinguished. In Chile, iodine is a coproduct of sodium nitrate production. Japan produced iodine from brines associated with natural gas production (table 6).

Legislation and Government Programs

The Annual Materials Plan of the U.S. Department of Defense proposed the sale of 453,593 kilograms (kg) (1 million pounds) of iodine for fiscal year 2000. The National Defense Authorization Act for Fiscal Year 2000 (Public Law 106-65), signed on October 5, 1999, did not change the previous authorization for disposal of all stock of crude iodine in excess of the National Defense Stockpile (NDS) goal. The law authorized the transfers of no more than $150 million from the NDS Transaction Fund equally to the operation and maintenance accounts of the Army, Navy, and Air Force, no more than $50 million each (section 304). Public Law 106-65 also obligated no more than $78.7 million of the NDS transaction fund for the operation of the NDS program. The law required the sale of authorized commodities that would result in receipts of $10 million by the end of fiscal year 2000; $100 million during the fiscal year ending September 30, 2004; and $300 million during the fiscal year ending September 30, 2009. On October 17, 2000, the Defense National Stockpile Center (DNSC) issued "Amendment No. 003 to Solicitation of Offers for DLA-Iodine-003" that changed the dates for offerings to February 21, May 16, and August 15, 2001. On October 29, 1999, "Amendment No. 002 to the Solicitation" changed the sale of the 453,593 kg to quarterly sales of 113,398 kg (250,000 pounds) and set subsequent offering dates for 1999 and 2000. On January 13, 2000, the DNSC announced the award of 19,050 kg (42,000 pounds) at a value of $270,000 ($14.17 per kilogram or $6.42 per pound). On March 8, 2000, the DNSC announced the sale of 2,270 kg (5,000 pounds) at a value of $31,000 ($13.67 per kilogram or $6.20 per pound). On

Iodine in the 20th Century

Iodine was first produced in the United States between 1917 and 1921 at an experimental station at Summerland in Santa Barbara County, CA. Large quantities of seaweed were harvested and used to produce acetic acid, potash fertilizers, and iodine. Iodine was first exploited commercially in 1916 in the form of potassium iodide as a remedy for goiter. In 1916, tincture of iodine was used as a disinfectant for cuts and abrasions and for sanitation. In 1939, Louis Daguerre published details of his method for making photographs on plated silver by using iodine vapor to form a thin coating of light sensitive silver iodide crystals.

Iodine production from underground brines began in the United States on August 2, 1928, near Shreveport, LA, using a process developed by Dow Chemical Co. The General Salt Co. began extracting iodine in 1928 from oilfield brines in the Signal Hill district in Long Beach, CA, using a charcoal process. The Louisiana plant closed in 1932, and the operation moved to California and was renamed the Jones Chemical Co. Deepwater Chemical Co. produced iodine in California from 1932 until 1960 by the silver iodide process. Domestic production in 1937 was reported to be 136,000 kilograms. In 1938, the Jones plant was incorporated as the Io-Dow Chemical Co. Production in 1940 was 564,000 kilograms. In 1961, Dow closed its plant in California and opened an iodine plant in Midland, MI, using underground brines associated with bromine production. Dow closed its Michigan plant in 1986.

In 1977, Woodward Iodine Corp. began production of iodine in Oklahoma. This plant was purchased by Ise Chemical Industries Co. Ltd. of Japan in 1994. In 1983, North American Brine Resources completed two miniplants in Kingfisher County, OK. In 1987, IOCHEM Corp. opened an iodine plant in Vici, OK. All production in Oklahoma was from gas brines.

In 2000, iodine was consumed in animal feed (45%), pharmaceuticals (27%), catalysts (10%), heat stabilizers (5%), and other applications (5%). About 27% of the iodine consumed during 2000, which was about 1.5 million kilograms, was from domestic production.

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June 7, 2000, the DNSC announced the sale of 2,270 kg (5,000 pounds) at a value of $30,000 ($13.23 per kilogram or $6.00 per pound). On August 31, 2000, the DNSC announced the sale of 14,300 kg (31,500 pounds) at a value of $188,000 ($13.21 per kilogram or $5.97 per pound). On December 5, 2000, the DNSC announced the sale of 11,200 kg (25,000 pounds) at a value of $150,00 ($13.23 per kilogram or $6.00 per pound). At yearend, 949,215 kg (108,500 pounds) was sold valued at $670,000, and the excess iodine was 1.7 million kilograms (Mkg) (3.8 million pounds) valued at $28 million ($16.44 per kilogram or $7.46 per pound).

In 1906, the Food and Drug Act was passed to ensure the safety and effectiveness of drugs and to set standards to determine which drugs can be sold over the counter and which ones require a prescription. During 1997 and 1998, online pharmacies were selling drugs to consumers without a valid prescription. Iodine and many of the products made from iodine are controlled substances. To protect consumers from illegal sales of drugs over the Internet, the Executive Office of the President unveiled an initiative in December that would require all online pharmacies to demonstrate that they comply with State and Federal laws and are licensed by the Food and Drug Administration (FDA). The maximum civil penalty would be raised to $500,000 from $1,000. The proposal would give the FDA subpoena power to investigate online pharmacies and provide $10 million to set up a rapid-response team to go after illicit drugs (Hileman, 2000).

One of the standards that is used for iodine is set by U.S. Pharmacopeia (USP). USP is an organization whose work is largely unknown, unrecognized, or overlooked by the public. USP sets and disseminates standards that ensure high-quality drugs for human and animal use, and it is a major element in drug regulation. The very foundation of drug regulation is delegated by statute to this private organization. USP was created in 1820 to bring some rational order to the pharmaceutical industry. At the first national convention, physicians made a list of safe and effective drugs and published this in what is now the USP. The USP was first revised in 1830 and every 10 years thereafter until 1970, when it was updated every 5 years; after 2002, it will be revised annually. In 1973, USP purchased the "National Formulary" (NF) from the American Pharmaceutical Association and combined the NF with the USP. The latest volume (USP24-NF19) was published in 2000 and included officially recognized standards for drugs and health care technologies (Ember, 2001).

Production

Domestic production data for iodine were derived from a voluntary survey of U.S. operations by the U.S. Geological Survey. The three companies to which a survey request was sent responded, representing 100% of the total production (tables 1, 6).

In 1987, IOCHEM Corp. began producing iodine by the blowing-out process at a plant 1.2 kilometers (km) east of Vici, Dewey County, OK. IOCHEM, the largest U.S. plant, was owned by the Kita family and Tomen Corp. The majority of the production was shipped to Schering AG of Germany under a long-term contract. IOCHEM reported having nine production wells and four injection wells with a total production capacity of 1,400 metric tons per year (t/yr) at Vici.

North American Brine Resources, owned by Beard Oil Co. (40%), Godoe Shigen (USA) Inc. (50%), and Mitsui & Co. (USA), Inc. (10%), began operating a miniplant at Dover in Kingfisher County, OK, in 1983. In 2000, the company operated one plant at an oilfield injection-disposal site that obtained brines from about 50 wells in the Oswego Formation. Iodine concentrations were as much as 1,200 parts per million (ppm). Its large plant in Woodward, OK, remained closed pending price increases.

Woodward Iodine Corp., which began production in 1977, was purchased by Asahi Glass Co. of Japan in 1984 and sold to Ise Chemical Industries Co. Ltd. of Japan in 1994. Woodward's plant in Woodward County, OK, produced iodine from 22 brine production wells, which used the blowing-out process, and injected waste through 10 injection wells. Mical Specialty Chemicals, Inc., a subsidiary of Mitsubishi International Corp., was the exclusive distributor for iodine produced by Woodward.

Consumption

Estimated end uses, by percentage, for iodine in 2000 were as follows: sanitation, 45%; animal feed, 27%; pharmaceuticals, 10%; catalysts, 8%; heat stabilizers, 5%; and other, 5%. Other smaller uses included inks and colorants, photographic chemicals, laboratory reagents, production of batteries, high-purity metals, motor fuels, and lubricants (table 2).

Commercial crude iodine normally has a minimum purity of 99.5%. Impurities are chiefly water, sulfuric acid, iron, and insoluble materials. The USP XVII specifies iodine content of not less than 99.8%. The Committee on Analytical Reagents of the American Chemical Society allows a maximum of 0.005% total bromine and chlorine and 0.010% nonvolatile matter.

Recommended daily allowances of iodine were as follows: infants, 40 to 40 micrograms (mg); children age 1 to 3 years, 70 mg, age 4 to 6 years, 90 mg, age 7 to 10 years, 120 mg, and age 11 and up, 150 mg; pregnant women, 175 mg; and lactating women, 200 mg. A quarter teaspoon of iodized table salt provides 95 mg of iodine. A 170 gram (6-ounce) portion of ocean fish provides 650 mg of iodine. Most people are able to meet their iodine requirements by eating iodized salt, plants grown in iodine-rich soil, seafood, and seaweed (Yahoo! Health, 2000, Iodine in diet, accessed October 30, 2000, at URL http://health.yahoo.com/health/diseases_and_conditions/disease_feed_data/iodine_in_diet).

In the human fetus, thyroid hormone is essential for the development of the central nervous system. The lack of thyroid hormone causes cretinism, which results in severe mental retardation and somatic growth. Until the 12th week of life, the sole source of thyroid hormone supply is maternal thyroid hormone. Recently, it was reported that the mild deficiency of thyroxine in maternal blood in the first or the second trimester of pregnancy would cause the impairment of cognitive capabilities of the offspring measured at 4 to 7 years after birth (Shishiba, 2000).

Arizona Chemical Division, which is a subsidiary company of International Paper Co., is a leading producer of pine chemicals

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that include tall oil and rosins, which use iodine as a stabilizer. These pine products were used globally for a variety of end uses, including adhesives, chewing gum, inks and coating, lubricants, rubber, plastics soaps and cleaners, and other markets (Arizona Chemical, July 26, 2000, Arizona Chemical launched new Internet site, accessed August 14, 2000, at URL http://www.arizonachemical.com/press/press_internet_7-26-00.htm).

International Paper put its Arizona Chemical pine chemical business up for sale as one part of a divestment program. Arizona Chemicals, headquartered in Jacksonville, FL, celebrated its 70th anniversary on February 8 (Chemical Market Reporter, 2000b). With about $700 million per year in sales, Arizona Chemical is the world's largest pine chemical company, fractionating tall oil and turpentine into chemicals for the adhesive coatings and inks industries (Chemical & Engineering News, 2000).

Crude tall oil originates as tall oil soap, which is separated from recovered black liquor in the Kraft pulping process. The soap is then acidified to yield crude tall oil. The tall oil is fractionated to produce fatty acids, pitch, and rosin. The pulp and paper industry is mature, and companies are increasingly pulping younger farmed pine trees that have a lower chemical content. The use of recycled fiber has reduced the growth of Kraft pulp production, and hardwood pulping yields no tall oil. Some tall oil derivative customers that use adhesives have shifted from rosin to hydrocarbon resins to ensure adequate supplies. Because of increases in crude oil prices, many of those hydrocarbons have faced significant pricing pressure (Naude, 2000).

Fatty acids are sold in competition with vegetable fatty acids to producers of detergents, oilfield chemicals, and paints, or converted to derivatives, such as dimer acid. Rosin is almost always chemically modified into esters or adducts that are used to make adhesives, inks, and paper size. Hercules Inc. is the only company in the United States still extracting rosin and turpentine from aged pine stumps. Akzo and Hercules compete with products from China, because certain customers require the white high-purity rosins derived from Southeastern U.S. pine gum. Georgia-Pacific completed a 50% expansion of its tall oil fractionation capacity in Crossett, AR, reducing the amount of tall oil it sells on the merchant market. Westvaco Corp. is the fourth largest tall oil producer making speciality adhesive (McCoy, 2000).

Hercules acquired the pulp and paper division of Quaker Chemical Corp. The business generates $8 million per year in revenues and provides specialty chemicals for tissue papermaking and pulping processes (Chemical Market Reporter, 2000b). Hercules announced that it entered into discussions to sell its pine and hydrocarbon resin business to an unidentified "major company." Hercules sells about $450 million per year of resins and has 1,500 employees. Its product line is divided between resins made by refining crude tall oil, a byproduct of making paper from pine trees, and resins made from the 5- and 9-carbon hydrocarbons fractions that are produced in ethylene plants (McCoy, 2000). Eastman Chemical Co. announced its intent to purchase Hercules Inc.'s hydrocarbon resins business and select portions of its rosins resins business (Chemical Market Reporter, 2000a).

Radiopaque agents are drugs used to help diagnose certain medical problems. They contain iodine, which absorbs x rays. Radiopague-diagnosed medical problems include biliary tract disorders, brain disorders, cardiac disease, central nervous system disorders, cerebrospinal fluid, disk disease, gastrointestinal gall bladder disorders, peritoneal disorders, splenic and portal vein disorders, urinary track disorders, and vascular disease.

Perfluoroalky iodides are produced in a variety of chemicals, such as water and oil repellent finishes, surfactants, and surface-treatment agents. Another use is in the preparation of a functionally substituted perfluoro (vinyl ether), which is a key monomer for perfluorinated ion-exchange membranes for the industrial chlor-alkali industry. The amount of iodine used for these intermediates was expected to consume 1,500 metric tons (t) of world production in 2000 (Yamabe, 2000).

Prices

Prices for iodine are negotiated on long- and short-term contracts. The average declared cost, insurance, and freight (c.i.f.) value for imported crude iodine was $14.58 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $14.38 per kilogram. The average declared c.i.f. value for imported crude iodine from Japan was $15.26 per kilogram. The average sale price of iodine sold from the DNSC was $16.44 per kilogram ($7.46 per pound). Published yearend U.S. prices for iodine and its primary compounds are listed in table 3.

Since 1977, when the first U.S. plant was built in Oklahoma, iodine c.i.f. prices per kilogram have been as follows: 1977, $4.39; 1978, $4.72; 1979, $6.57; 1980, $13.80; 1981, $13.12; 1982, $12.92; 1983, $12.06; 1984, $10.58; 1985, $11.86; 1986, $12.52; 1987, $15.26; 1988, $17.46; 1989, $17.67; 1990, $15.19; 1991, $10.16; 1992, $9.03; 1993, $7.90; 1994, $7.56; 1995, $9.88; 1996, $12.90; 1997, $14.66; 1998, $16.45; and 1999, $16.15. U.S. production decreased to 1.5 Mkg from 1.6 Mkg, and world production remained at 18 Mkg in 2000.

Iodine prices are stable compared to the volatility experienced during the 1980s and 1990s. In the second half of the 1980s, iodine prices increased as a result of strong demand and reduced supply owing to fire damage at iodine production facilities in Chile. Demand and prices decreased between 1990 and 1991. New capacity in Chile during 1996 and 1997 combined with increased sales from the DNSC caused an oversupply of iodine and a price decrease (Mineral Price Watch, 2001).

Foreign Trade

The U.S. Government adopted the harmonized commodity description and coding system as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. It includes resublimed and crude iodine under the same code and a free duty rate. Values that differ significantly could be a result of items being placed in the wrong category (tables 4, 5).

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World Review

The worldwide production of iodine in 2000 was estimated to be approximately 18,000 t, of which 9,100 t (51%) was from Chile, and 6,100 t (34%) was produced in Japan. The industrial demands of iodine are still increasing, and areas of applications are expanding beyond the established markets, which are as follows: various additives (23%), x-ray contrast media (22%), germicides and disinfectants (17%), catalysts (15%), pharmaceuticals (9%), and other (14%) (Yamabe, 2000).

Azerbaijan.—This nation's economy is based on oil and natural gas production; oilfield brines contained iodine and bromine. Enterprises and individuals engaged in mineral extraction are subject to a mineral fields or subsoil tax. The tax is applied to the net income received from the sale of the product at rates ranging from 3% to 26%. According to the list approved by the Cabinet of Ministers in June 1996, the tax is applied to iodine and mineral water (Oil and Gas Chemistry, 2000).

The Neftchala iodine-bromine plant in Neftchala planned to conduct a tender to attract investment to modernize production to include production of potassium iodide and other iodine derivites. Investment of $1.4 million over 1.5 years is required. A production line for iodine-containing salt with a capacity of 100,000 t/yr has been constructed and commisssioned. The iodine is recovered from brines associated with the Neftchala and Khillinsky oilfields in the Prikurinsky Basin. The plant design capacity is 800 t/yr of iodine but is presently idle because of the need for capital for repairs (Industrial Minerals, 2000).

Chile.—Chile was the leading producing country of iodine. In response to falling prices and demand, Compania de Salitre y Yodo reduced its iodine output to 2,000 t/yr from 2,400 t/yr. DSM Mineraa SA cut production at the Iris-La Granja site by 30% in 1999. Sociedad Química y Minera de Chile SA (SQM) continued to idle two units.

Atacama Minerals Chile SCM, a subsidiary of Atacama Minerals Corp., Vancouver, Canada, finalized an agreement with ACF Minera S.A. to develop the Aguas Blancas project near Antofagasta, Chile. The agreement includes plans for a larger capacity heap-leach operation to allow for production of 720 t/yr. Once the iodine facilities are operational, the plant will begin production of the potassium nitrate and sodium sulfate reserves (Mining Engineering, 2000).

The nitrate and iodine project at Pampa Dominador was being developed by Minera CeroImán SCM (MCI), a wholly owned subsidiary of Minera Soledad S.A., a Chilean private company established in 1988. The deposit is located within the Atacama Desert at an altitude of 1,750 meters (m) and 160 km southeast of the Pacific port of Antofagasta. The site is the location of the former Oficina Salitrera Dominador, which operated from 1925 to 1930. A total of 8,750 hectares (ha) of MCI's mining property at Pampa Dominador is the main deposit for the nitrate and iodine project. An export program that covered about 5,000 ha was carried out during 1998. Nine ore bodies with average ore strata thickness of 2 m and overburden thickness averaging 0.6 m were defined. Reserves calculated to January 1999 included proven reserves of 540 Mkg of iodine with probable reserves of 620 Mkg iodine (Minera CerroImán, 2000).

The Potash Corporation of Saskatchewan, Inc. (PCS) began production from the Yumbes Mine in July. About 18 t of iodine was shipped from the mine to the United Kingdom. Planned production will include 40 t/yr of iodine. PCS has put about $14 million into the projet since acquiring the project for $36 million in 1999 (Green Markets, 2000).

Cosayach S.A. was preparing to begin production of nitrates at its operation near Poao Almonte in the northern Chile. Production also included limited amounts of iodine (Fertilizer Week, 2000).

All of SQM's production was from surface mines at Pedro de Valdivia and Maria Elena and from mine tailings at Sierra Gordo. Exports of 80% of the iodine produced go to the following areas: Europe (40%), the United States (27%), South America (21%), Asia (7%), and Africa (5%) (Eugenio Ponce, International Fertilizer Industry Association, 1998, Chile—Specialty fertilizers and industrial chemicals from two unique resources, accessed May 23, 2001, at URL http://www.fertilizer.org/publish/biblio/biblio99/conf4.htm).

Three of SQM's top officials were fined a total of $32,000 by Chile's Superintendencia de Valores Y Seguros (SVS). The SVS alleged that the president of Ora Blanco did not inform the Commission that they had set up two companies that held ultimate control of SQM. Patco Trust and Holywell Trust were registered in the British Virgin Islands in 1994 but were not declared to the SVS until 1999 (Industrial Minerals, 2001).

All iodine processed in Chile uses sulfuric acid. The use of a sulfuric-acid-nitrate mixture could generate fumes and leakages, with inherent risk to the workers. Sulfur melting and sulfur dioxide generation was performed using the same technology in all Chilean plants. Only the age of the plant makes the difference in emissions to the atmosphere. Using kerosene in a solvent extraction process puts plants at increased risk of fire (Munoz, 2000).

India.—The duty on iodine was reduced to 10% from 25%. The chemical industry has become a major producer and exporter of chemicals in the world partly because of scaling down the import duty on chemicals widely used in the industry (Ministry of Finance,1997, Public finance—Tax measures, accessed January 17, 2001, at URL http://finmin.nic.in/indiabudget/es97/CHAP2.htm).

Indonesia.—P.T. Lamindo Ekaperdana reported brines containing 100 ppm of iodine. The company planned to build a 250 t/yr iodine plant (Tampi Mariko, P.T. Lamindo Ekaperdana, written commun., 2000).

Japan.—Japan was the world's second largest producer of iodine (table 6). Iodine was manufactured in Chiba, Miyazaki, and Niigata Prefectures; Chiba Prefecture accounted for about 90% of all production in Japan. The following 8 companies operated 11 plants in Japan during 1999: Ise Chemical Co, Ltd. 2 plants in Chiba Prefecture and 1 in Miyazaki Prefecture, 300 metric tons per month (t/mo); Kanto Natural Gas Development Co., Ltd. (KNG), Chiba Prefecture, 100 t/mo; Godo Shigen Sangyo Co., Ltd., Chiba Prefecture, 200 t/mo; Japan Energy Development Co., Ltd., Niigata Prefecture, 30 t/mo; Teikoku Oil Co. Ltd, Chiba Prefecture, 50 t/mo; Toho Earthtech, Inc., Niigata Prefecture, 60 t/mo; Nippoh Chemicals Co., Ltd., Chiba Prefecture, 60 t/mo; and Nihon Tennen Gas Co., Ltd., 2 in Chiba Prefecture, 100 t/mo.

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Sumitomo Chemical Co. and Mitsui Chemicals Inc. announced a $1.6 billion merger targeted for 2003. This would create the largest chemical company in Asia and fifth largest in the world. Mitsui is a producer of iodine in the United States. Mitsui and KNG have a joint venture (JI Chemicals, Inc.) to develop iodine derivative products (Kanto Natural Gas Development Co., Ltd.).

KNG was established in 1931 and uses the ion-exchange resin and the blowing-out method to produce iodine. In the ion-exchange resin method, sand and other impurities are removed by precipitation or filtration. The iodine is then separated from the brine by means of an oxidizing agent and collected by adsorption on the ion-exchange resin. The iodine is separated from the resin by elution, then is crystallized and refined. The blowing-out method makes use of the ease with which iodine evaporates and is suitable for use with high-temperature brine. After removal of sand and other impurities by precipitation and separation of the iodine using an oxidizing agent, the brine is exposed to air. The iodine evaporates and is then absorbed, crystallized, and refined. The brines average 110 ppm and the iodine produced is 99.7% pure. International Standards Organization (ISO) 9002 certification was granted in 1995 (Kanto Natural Gas Development Co., Ltd.).

Nihon was established in 1940, and iodine production began in 1944. In 1969, a new plant was built in Yokoshiba-machi, and in 1973 and 1988, new plants were built in Chiba Perfecture. Equipment for iodine adsorption changed to sloping fluidized bed (SFB) in June 1993. The plant gained ISO 9002 certificiation in 1996. The iodine was produced by two processes: the extraction by resins discussed before and the SFB developed to pass brine through the adsorption tower without filtration. The elution of the resin produces a concentrated iodine solution. Iodine is crystallized by oxidizers and is separated and refined into a flaked product (Nihon Tennen Gas Co., Ltd.).

The Forum on Iodine Utilization (FIU), which was created in June 1998 with the cooperation of industrial, governmental, and academic circles, reached 300 members in 1999. The FIU actively promotes the development of the iodine industry by a variety of symposiums on basic research and applications. The third FIU symposium was held at Chiba University in 2000. It included 17 talks and 30 poster sessions.

Iodine deficiency disorder (IDD) occurs in areas where iodine content in food is very low. Developed countries have realized the problem and require iodized salt for consumption. In 1986, a representative of Japan attended the International Council for Control of Iodine Deficiency Disorder's inaugral meeting in Nepal. A common agenda was established between Japan and the United States in 1996 to promote cooperation on IDD problems. The Japan International Cooperation Agency and the government of Chiba Prefecture started the Assistance for Mongolia Program in 1997 (Irie, 2000).

Recent studies on iodine in brines from the late Pliocene age (a period between 5 and 1.8 million years ago) in Kazusa Formation in Chiba, Japan, showed that the iodine orginated during the Palaeogen age, a period in the Cenozoic Era between 65 to 54 million years ago, which is much older that the layers in which the brines occur. The results might indicate that iodine in these brines is not derived from the reservoir formation but is released from marine sediments undergoing subduction in this region (Muramatsu, 2000).

Russia.—Iodine content ranges from 30 to 90 milligrams per liter in 20 oilfields of Northern Sakhalin. The highest grade field is the Odoptu field where recovery of the iodine content could produce 30 metric tons per day of iodine (Elena Sabirova, American Business Center, written commun., March 19, 2001).

Turkmenistan.—Iodine is produced in Turkmenistan and Azerbaijan from underground brines. The Nebitdag plant was in Vyshka, 26 km southwest of Nebitdag City in Balkan Velayat. The plant extracts bromine and iodine from underground brines of the Nebitdag-Monjoukley deposit. The plant reported production capacities of 255 t/yr of iodine and 3,200 t/yr of ferrous bromide, as well as 1,300 t/yr of bromine derivatives and 100 t/yr of sodium hypochlorite. It was commissioned in 1969 and had 33 employees (table 6).

Current Research and Technology

Three scientist received the Nobel Prize in Chemistry for developing the important new field of electrically conductive polymers. The polymer was produced in 1977. By doping polyacetylene with iodine, the polymer film conductivity increased. On exposure to iodine, polyacetylene is oxidatively doped, and the polymer chain loses an electron, leaving a hole or positive charge. When the hole is filled by an electron jumping from a neighboring position, a new hole is created. As the cascade continues, the positive charge can migrate down the conjugated chain (Dagani, 2000).

Researchers at the Massachusetts Institute of Technology devised a coating, hexyl-PVP, that can kill 99% of common disease-causing organisms. PVP is the acronym for polyvinylpyrrolidone. The polymer kills bacteria by a powerful chemical-electrical action, a permanent positive charge that destroys bacterial cell walls and membranes. The antibacterial coating could be incorporated during manufacture so that the surface of many products could be permanently sterile (Midfully.org, May 22, 2001, Hexyl-PVP special coating kills germs, researcher says, accessed June 28, 2001, at URL http://www.mindfully.org/Plastic/Hexyl-PVP-Kills-Germs.htm).

PVP polymers (PVPP) are dye-receptive agents, binders, complexing agents, detoxicants, film formers, stabilizers, protective colloidal, and suspending agents. The polymers are available in several viscosity grades, ranging from very low to very high molecular weight, giving this family of products great flexibility across a wide range of industries (International Specialty Products Corp., 1999, PVP polyvinylpyrrolidone polymers, accessed January 22, 2001, at URL http://www.ispcorp.com/products/industrial/ind11.html).

International Specialty Products Corp. (ISP) offers a tablet disintegrantor that is based on PVPP technology similar to that used by pharmaceutical tablet formulators. The PVPP swells on contact with water, causing rapid tablet breakup and helping soap to dissolve quickly in the wash. ISP is planning a series of blends of PVPP with other disintegrant materials to offer a range of cost and performance options (McCoy, 2001).

Researchers at the Chiba Institute of Technology developed an aluminumoxidation coating impregnated with an iodine compound by an electrochemical method. The bactericidal

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activities of the coating were effective against various molds and bacteria (Takaya, 2000).

The adsorpiton of iodine on single crystal electrodesis is one of the most intensively studied electrochemical processes. Recent studies at Tohoku University disclosed a novel property of iodine-modified electrodes because the adsorption of organic molecules formed highly ordered molecular arrays. The internal molecular structure, orientation, and packing arrangement were clearly visualized with near-atomic resolution by in situ scanning tunneling microscopy (Itaya, 2000).

Hydrogen iodide gas showed superior characteristics for etching materials, such as indium tin oxide (ITO) film, used for pixel electrodes of liquid crystal displays. Although wet etching is still the major process for ITO etching, the dry etching process makes sharper etching compared with other gases (Sadamoto and others, 2000).

Iodine-125 is the primary radionuclide for in vitro application due to its 60 day half-life and low energy photon emission. The long half-life permits the preparation of radioimmunoassay and immunometric radioassay. Iodine-123 has good imaging properties for planar and single-photon emission computed tomography imaging. Its physical properties include a half-life of 13 hours. Iodine-131 has a relatively long half-life (8 days) and emits both gamma and beta rays, which render this radionuclide useful for in vivo radiotherapy of cancer and Basedow's goiter. Iodine-123 and iodine-131 also are applied to label such proteins as antibodies against tumor cells for both external imaging and targeted radiotherapy. Monoclonal antibodies have been used to deliver radionuclides to target tissues for diagnostic and therapeutic purposes. The use of radiolabeled intact antibodies has shown limitations, such as slow penetration into tumors. Studies at Chiba University indicated that an iodine organic reagent (HML) would be a promising reagent for targeted imaging and therapy using antibody fragments as vehicles. These studies suggested that radiochemically designing antibody fragments that liberate radiometabolites of urinary excretion by the action of brush border enzymes may constitute a new strategy for reducing the renal radioactivity levels of antibody fragments (Arano, 2000).

Chemists at the Massachusetts Institute of Technology found that a chiral catalyst derived from 4-pyrrolidinopyridine and O-acylated azlactone exhibits the correct reactivity for catalytic kinetic resolution of racemic primary amines. The iodine catalyst reacts more rapidly with the catalyst than the amine, allowing the catalyst to exert its chiral influence before the reaction is complete (Chemical & Engineering News, 2001).

Evergreen Nylon Recycling llc (ENR) was named Recycler of the Year by the Plastics Recycling Division of the Society of Plastics Engineers. ENR is a joint venture of Honeywell International Inc. and DSM Chemicals North America Inc. The company converts postconsumer nylon-6 carpet and other nylon-6 waste that required iodine compounds as a stabilizer during manufacturing into caprolactam, the raw material for nylon-6. Type 6 nylon is used in products that include automotive parts, residential and commercial carpets, engineered plastics, films, packaging, and sporting goods (Reese, 2000).

At the 198th meeting of the Electrochemical Society in Phoenix, AZ, 1,200 scientific presentations were presented, including one on the use of lithium-iodide batteries. The plenary lecture focused on electrochemistry in the service of medicine. The vice president of research and development at battery manufacturer Wilson Greatbatch, Clarence, NY, gave an overview of power sources used in implantable medical devices. Nearly all pacemakers being implanted today run on lithium-iodide batteries, and the cells are extremely stable with some real-time tests showing these batteries running continuously for nearly 25 years. The life expectancy of the battery is determined by its size (Jacoby, 2000).

Chemists at the University of Lausanne, Switzerland, have invented an asymmetric carbon-carbon bond-forming reaction that could be useful in synthesis. Methyl iodide is used in part of the reaction (Stinson, 2000).

Scientists at the National Institute of Radiological Science (Japan) and Geochemisches Institut (Germany) analyzed 300 rocks and major units and subunits of the Earth's crust for iodine. The high average concentrations were 30 ppm of iodine in deep-sea carbonates and 2.5 ppm iodine in continental limestones. Seawater averaged 50 parts per billion iodine (Muramatsu and Wedepohl, 1998).

At a session of the American Chemical Society's national meeting in San Francisco in March 2000, European researchers presented data confirming that a wide variety of drugs and their metabolites are showing up in low concentrations in waterways of Croatia, Germany, Greece, and Switzerland. One of the pharmaceuticals identified in the environment is iopromide, an x-ray contrast media. Pharmaceuticals and personal care products can end up in the environment if not properly disposed. In the United States, the topic falls within the regulatory responsibilities of the U.S. Environmental Protection Agency and the Food and Drug Administration (Zurer, 2000).

Outlook

During the past decade, iodine production capacity in Chile and the United States has doubled, thus ensuring an adequate future world supply. Overall growth in traditional uses is projected to grow by as much as 2% per year. Uses for iodine in specialty chemicals have remained stable.

Recent developments in digital imaging can produce electronic prints and overhead transparencies without the need for wet processing. By using a digital camera or scanning the film and converting to digital tapes, the images are produced and stored on disks, hard drives, and tape. Digital imaging is used for recording most sporting events, game shows, and some situation comedies for television broadcast. From 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter (mm) motion picture film and then transferred to video tape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film because of better image quality. A frame of 35-mm color negative film contains about 6.6 million pixels, about 15 times that of the best high-definition television system and 4 times that of the digital systems now in development. Most popular home video rentals have been box office movie hits that were filmed and then transferred to video. In the next decade, future uses of iodine in films and processing could be limited to specialty imaging as digital imagery technology

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improves and the cost of equipment becomes more affordable.

New uses of fluoroiodocarbon as halogen replacements may cause an increased demand for iodine. More tests need to be completed on the iodated fluorocarbons before they are acceptable, but preliminary tests are promising. Supplemental programs designed to alleviate iodine deficiency disorder in China and India are consuming large amounts of iodine. X-ray contrast media, which contain as much as 60% iodine, will continue to grow between 4% and 5% per year. In Chile and Mexico, individual water purification units that use iodine are a new application of a historical purification process. Purification applications could become significant consumers of iodine.

References Cited

Arano, Yasushi, 2000, Chemical design of radio iodination reagents for targeted imaging and radiotherapy of tumor utilization using antibody fragments as vehicles, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co., Ltd, p. 158.

Chemical & Engineering News, 2000, Business concentrates—International Paper to sell Arizona Chemical unit: Chemical & Engineering News, v. 78, no. 50, December 11, p. 13.

———2001, Science & technology concentrates—Catalyst for resolving racemic amines: Chemical & Engineering News, v. 79, no. 3, January 15, p. 39.

Chemical Market Reporter, 2000a, Eastman unveils a new business platform for resins growth: Chemical Market Reporter, v. 258, no. 13, September 25, p. 26.

———2000b, Hercules acquires paper unit: Chemical Market Reporter, v. 257, no. 23, June 5, p. 3.

Dagani, R., 2000, Electrifying plastics: Chemical & Engineering News, v. 78, no. 42, October 16, p. 4-5.

Ember, L.R., 2001, Raising the bar for quality drugs: Chemical & Engineering News, v. 79, no. 12, March 19, p. 26-27.

Fertilizer Week, 2000, Chile's Cosayach set to KNO_3 start-up: Fertilizer Week, v. 14, no. 27, November 13, p. 1.

Green Markets, 2000, Chile: Green Markets, v. 24, no. 33, August 14, p. 8.

Hileman, Bette, 2000, Seeking control of Internet drug sales: Chemical & Engineering News, v. 78, no. 3, January 17, p. 42-43.

Industrial Minerals, 2000, News & events—Iodine-bromine plant needs investor: Industrial Minerals, no. 399, December, p. 23.

———2001, Chile—SQM and Chemetall form $MgCl_2$ j-v: Industrial Minerals, no. 400, January, p. 12.

Irie, Minoru, 2000, Iodine deficiency disorders (IDD), *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 13.

Itaya, Kingo, 2000, Structures and properties of iodine adlayers on single crystal electrodes, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 93.

Jacoby, Mitch, 2000, Chemistry of all sorts of electrodes: Chemical & Engineering News, v. 78, no. 49, December 4, p. 65-72.

Kanto Natural Gas Development Co., Ltd, [undated], Corporate profile: Tokyo, Japan, Kanto Natural Gas Development Co., Ltd., 9 p.

McCoy, Michael, 2000, Tall (oil) tale of pine chemicals: Chemical & Engineering News, v. 78, no. 13, March 27, p. 14-15.

———2001, Additives—Where all the magic is: Chemical & Engineering News, v. 79, no. 3, January 15, p. 26.

Minera CerroImán, 2000, Dominador project: Minera CerroImán, March, p. 15.

Mineral Price Watch, 2001, Iodine market future supply key to stability: Mineral Price Watch, March, p. 7-9.

Mining Engineering, 2000, Chilean iodine property developed: Mining Engineering, v. 52, no. 11, November, p. 15.

Munoz, R.L., 2000, Iodine production technologies in Chile and their impact on product quality and SHE aspects, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 21.

Muramatsu, Yasuyuki, and Wedepohl, K.H., 1998, The distribution of iodine in the Earth's crust: Chemical Geology, v. 147, p. 201-206.

Muramatsu, Y., 2000, Origin of iodine rich brine in the Kazusa formation, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 123.

Naude, Alice, 2000, Tall oil derivatives are up—Future supply to fall short: Chemical Market Reporter, v. 257, no. 22, May 29, p. 12-13.

Nihon Tennen Gas Co. Ltd., [undated], Corporate profile: Chiba, Japan, Nihon Tennen Gas. Co. Ltd., 13 p.

Oil and Gas Chemistry, 2000, Azerbaijan oil and gas tax guide: Oil and Gas Chemistry, no. 3, March 7, 10 p.

Reese, K.H., 2000, Newscripts—Nylon recycler honored: Chemical & Engineering News, v. 78, no. 51, December 18, p. 64.

Sadamoto, Mitsuru, Yanagawa, Noriyuki, Sasako, Haruo, and Kaiho, Tatsuo, 2000, Hydrogen iodide as dry etching gas, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 117.

Shishiba, Yoshimasa, 2000, Effect of thyroid hormone in human from evolutional point of view, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 9.

Stinson, Stephen, 2000, One pot, four compenents, one asymmetric C-C bond, two chiral centers: Chemical & Engineering News, v. 78, no. 20, p. 50.

Takaya, Matsufumi, 2000, Surface treatment of aluminum alloys using iodine, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 25.

Yamabe, Masaaki, 2000, The role of iodine in fluorchemical industries, *in* Symposium on Iodine Utilization, 3d, Chiba, Japan, 2000, Proceedings: Chiba, Japan, Kanto Natural Gas Development Co. Ltd, p. 29.

Zurer, P.S., 2000, Drugs down the drain: Chemical & Engineering News, v. 78, no. 15, April 10, p. 51-53.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iodine. Ch. in Mineral Commodity Summaries, annual.

Iodine. Ch. in Minerals Yearbook, annual.

Iodine. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Iodine. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production	1,270	1,320	1,490	1,620	1,470
Imports for domestic consumption 2/ 3/	4,860	6,380	5,960	5,430	4,790
Exports 2/ 3/	2,410	2,760	2,790	1,130	886
Consumption:					
Reported 4/	3,920	4,500	4,100	4,540	3,990
Apparent 5/	3,700	5,140	4,950	5,990	5,420
Price, imports, average c.i.f. value, dollars per kilogram 2/	$12.82	$14.74	$16.45	$16.15	$14.59
World, production	14,100 r/	15,700 r/	18,600 r/	18,400 r/	18,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except prices.

2/ U.S. Census Bureau.

3/ Only the crude iodine "content" of the potassium iodide as declared by tables 4 and 5 is incorporated in data or calculations for this table.

4/ Reported by voluntary response to the U.S. Geological Survey from a survey of domestic establishments.

5/ Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

TABLE 2
DOMESTIC CONSUMPTION OF CRUDE IODINE, BY PRODUCT 1/

(Thousand kilograms)

	1999		2000	
Product	Number of plants	Quantity	Number of plants	Quantity
Inorganic compounds:				
Resublimed iodine	9	196	11	205
Potassium iodide	9	676	9	496
Sodium iodide	7	373	7	403
Ammonium iodide	1	W	1	W
Calcium iodate	2	W	1	W
Cuprous iodide	2	W	2	W
Hydriodic acid	4	177	3	175
Potassium iodate	3	70	3	94
Other inorganic compounds	6	367	7	799
Total	(2/)	1,860	(2/)	2,170
Organic compounds:				
Ethylenediamine dihydroiodide	4	877	3	176
Methyl and/or ethyl iodide	3	68	2	W
Povidone-iodine (idophors)	4	645	--	--
Other organic compounds	8	1,090	7	1,640
Total	(2/)	2,680	(2/)	1,820
Grand total:				
Reported consumption 3/	(2/)	4,540	(2/)	3,990
Apparent consumption 4/	(2/)	5,990	(2/)	5,420

W Withheld to avoid disclosing company proprietary data; included with "Other inorganic compounds" and "Other organic compounds." -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Nonadditive because some plants produce more than one product concurrently.

3/ Reported by voluntary response to the U.S. Geological Survey in a survey of domestic establishments.

4/ Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

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TABLE 3
YEAREND 2000 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

(Dollars)

Elemental iodine/compounds	Value 1/	
	Per kilogram	Per pound
Calcium iodate, FCC drums, f.o.b. works	16.42	7.45
Calcium iodide, 50-kilogram drums, f.o.b. works	30.00	13.61
Iodine, crude, drums	19.00-21.00	8.62-9.53
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	26.48	12.01
Sodium iodide, U.S.P., crystals, 5,000-pound lots, drums, freight-equalized	36.38	16.50

1/ Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Market Reporter. Current Prices of Chemicals and Related Materials; v. 258, no. 25, December 18, 2000, p. 23-28.

TABLE 4
U.S. IMPORTS OF CRUDE IODINE AND POTASSIUM IODIDE FOR DOMESTIC CONSUMPTION, BY COUNTRY OF ORIGIN 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1999		2000	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude:				
Canada	4	33	--	--
Cayman Islands	--	--	18	234
Chile	3,490	54,800	3,450	49,100
China	--	--	5	47
Germany	3	52	--	--
Japan	1,480	25,300	1,220	18,600
Russia	109	1,880	87	1,260
Switzerland	36	540	--	--
Other 4/	21	365	7	68
Total	5,140	83,000	4,790	69,400
Iodide, potassium: 5/				
Canada	247	4,310	222	3,720
Chile	36	622	37	590
Japan	1	9	1	20
Other 6/	9	154	223	3,330
Total	293	5,090	483	7,660
Grand total	5,430	88,100	5,270	77,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Import information for crude iodine and potassium iodide are reported by HTS numbers 2801.20.0000 and 2827.60.2000, respectively.
3/ Declared cost, insurance, freight (c.i.f.) valuation.
4/ Includes Georgia (1999), India, Mexico (2000), and the Netherlands (1999).
5/ Gross potassium iodide contains 76% crude iodine.
6/ Includes Denmark (1999), France (2000), Germany, India (1999), Israel, and the Netherlands (2000).

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE,
BY COUNTRY OF DESTINATION 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1999		2000	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude/resublimed:				
Canada	28	551	69	1,160
France	34	564	45	716
Germany	686	10,800	597	8,330
India	22	375	(4/)	5
Mexico	166	2,170	120	1,630
Netherlands	34	630	--	--
United Kingdom	--	--	68	978
Other 5/	138	2,340	109	1,780
Total	1,110	17,400	1,010	14,600
Iodide, potassium: 6/				
Australia	1	20	--	--
Mexico	7	120	8	141
Netherlands	2	50	3	49
Thailand	(4/)	9	--	--
Turkey	10	205	--	--
Other 7/	5	126	11	198
Total	25	530	22	388
Grand total	1,130	18,000	1,130	15,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Export information for iodine, crude/resublimed and potassium iodide are reported by HTS numbers 2801.20.0000 and 2827.60.2000, respectively.
3/ Declared free alongside ship (f.a.s.) valuation.
4/ Less than 1/2 unit.
5/ Includes Belgium, Columbia (2000), Costa Rica (1999), the Dominican Republic (2000), Denmark (2000), El Salvador (2000), Italy (1999), Japan, the Republic of Korea (1999), Norway (2000), Portugal (1999), Spain (1999), Taiwan (2000), Thailand, and Venezuela.
6/ Gross potassium iodide contains 76% crude iodine.
7/ Includes Denmark (1999), France (1999), Germany (2000), Indonesia (1999), Jamaica (1999) Malaysia (1999), Singapore (1999), Switzerland (2000), Taiwan (2000), the United Kingdom (1999), and Vietnam (1999).

Source: U.S. Census Bureau.

TABLE 6
CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country	1996	1997	1998	1999	2000 e/
Azerbaijan e/	300	300	300	300	300
Chile 3/	5,514	7,154	9,722	9,317 r/	9,100
China e/	500	500	500	500	500
Indonesia e/	75	83	66	70	70
Japan	6,178	6,036	6,142	6,152 r/	6,100
Russia e/	250 r/	250 r/	280 r/	300 r/	300
Turkmenistan	35	87	90 e/	150 e/	150
United States	1,270	1,320	1,490	1,620	1,470 4/
Uzbekistan e/	--	--	1	2	2
Total	14,100 r/	15,700 r/	18,600 r/	18,400 r/	18,000

e/ Estimated. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through June 8, 2001.
3/ Includes iodine production reported by Servicio Nacional de Geologia y Minería.
4/ Reported figure.

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IRON AND STEEL

By Michael D. Fenton

Domestic survey data and tables were prepared by Nicholas Muniz, statistical assistant, and the world production tables were prepared by Linder Roberts (pig iron) and Ronald L. Hatch (steel), international data coordinators.

The U.S. steel industry was adversely affected by the 1997 Asian financial crisis as Asian demand for steel and ferrous scrap declined, Asian currency exchange rates declined, and inexpensive steel became available for export to U.S. markets from excess Asian steel-producing capacity. Domestic steel product manufacturers welcomed inexpensive imports, but domestic steel producers were forced to reduce production and scrap consumption, which led to an oversupply of scrap and a plunge of steel and scrap prices. Through 1999, the steel-producing and scrap industries were on the rebound owing primarily to resurging Asian economies and increasing steel demand in Asia and the United States. As 2000 began, steel producers and scrap suppliers were increasingly optimistic that they were on track for a slow but certain recovery to precrisis economic levels. However, to the detriment of these sectors, the U.S. 117-month economic expansion—the longest in U.S. history, beginning in March 1991—was showing signs of weakening. The nation's economy displayed an annual growth rate of 5.2% in the first half of the year, 1.6% in the second half of the year, and only 1% in the fourth quarter—the weakest performance since the second quarter of 1995 (Leo Kamp, The 2001 economy overview, TIAA-CREF Web Center, accessed October 12, 2001, at URL http://www.tiaa-cref.org/siteline/archive/gen0104_065.html). Concurrently, prices of electricity and natural gas were increasing significantly, and steel imports, which declined in 1999 below the 1998 level, began to increase again in 2000. Prices for steel products and ferrous scrap again plunged to record levels. Although for relief the U.S. steel industry filed trade cases against dumped hot-rolled carbon steel from 11 countries, it was becoming clear that a more fundamental problem was that the world had excess steelmaking capacity. Steelmakers can produce 15% more steel than the world market demands, but are adding 2% more capacity each year (Iron and Steelmaker, 2001; Matthews, 2000). Data regarding U.S. production of iron and steel and shipments of steel mill products were reported by the American Iron and Steel Institute (AISI). These data can be regarded as representing 100% of the raw steel producers in the United States. World production of iron and steel is reported by the International Iron and Steel Institute (IISI) and by foreign government agencies. Consistent with international usage and Federal Government policy, the U.S. Geological Survey reported all data on iron and steel in metric units, unless otherwise noted.

Environment

In December, the U.S. Environmental Protection Agency (EPA) proposed new waste water release and treatment standards for iron and steel manufacturing facilities involved in cokemaking, ironmaking, integrated and nonintegrated

Steel in the 20th Century

By early 1900, the United States led the world in steel production contributing about 36% of the world's output, followed by the German Empire (23%), the United Kingdom (17%), and Russia (10%). The Bessemer, open hearth, and crucible furnaces were used in the United States for 67%, 32%, and 1%, respectively, of steel production. Iron and steel scrap was usually 45% to 55% of the charge used in open hearth furnaces, although a 100% scrap charge was possible. Industries in the United States entered a period of extraordinary prosperity beginning in 1899. Labor, both skilled and unskilled, had never been in greater demand in the United States, and wages increased significantly. Demand for all types of manufactured products increased as labor wages increased, and mills and factories operated at their fullest capacities to satisfy demand. The steel industry shared in this prosperity because it satisfied a growing demand for steel in consumer goods; locomotives, rail cars, and rails for expanding railroads; railroad and road bridges; ships; public buildings; electricity generation plants; and water supply facilities. Imports of steel mill products (1.8 million tons) exceeded exports (0.7 million tons) as domestic demand for U.S. steel increased and European demand decreased.

In 2000, the United States ranked third in the world as a producer, accounting for 12% of world production. The steel production of China and Japan exceeded that of the United States with 15% and 13% of world output, respectively. The Bessemer, open hearth, and crucible furnaces were replaced in the steelmaking process by the basic oxygen and electric arc furnaces, which made 53% and 46% of U.S. steel production, respectively. The charge of the electric arc furnaces was usually nearly 100% iron and steel scrap. January 2000 marked the 105th month of an unprecedented period of economic growth, during which U.S. industry, including the steel sector, successfully met the challenges of high domestic demand and global competition. The prosperity of steelmakers was marred when declining Asian demand for steel, excess Asian steel-producing capacity, and unusually low steel prices that began with the Asian financial crisis of 1997 brought about a major influx of steel from Asia to the United States. Imports of steel mill products (34.4 million tons) exceeded exports (5.9 million tons) in 2000 and accounted for 29% of U.S. apparent consumption of steel. Domestic steel producers sought relief in the form of tariffs and quotas imposed by the U.S. International Trade Commission in an effort to reduce imports.

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steelmaking, steel finishing, direct-iron reduction and briquetting, and forging (Bourge, 2001). EPA estimates that the changes would reduce pollution by at least 952,000 metric tons per year with the value of benefits ranging from $1.1 million to $2.7 million. Estimated compliance costs range from $56.5 million to $61.4 million per year.

Production

Production of raw steel in the United States increased to 102 million metric tons (Mt) from 97.4 Mt in 1999 (table 1). AISI estimated raw steel production capability to be 118 Mt, up from 116 Mt (revised) in 1999. Production represented 86.1% of estimated capability, compared with 83.8% in 1999.

Integrated steel producers smelted iron ores to liquid iron in blast furnaces and used basic oxygen furnaces to refine this iron with some scrap to produce raw liquid steel. The basic oxygen process was used to make 54.0 Mt of steel (American Iron and Steel Institute, 2000, p. 74). The use of this process declined slightly to 53.0% of total steel production in 2000 from 53.8% in 1999. The integrated steel industry in the United States consisted of 13 companies operating ironmaking and steelmaking facilities at 19 locations (Iron and Steelmaker, 2000). Several of these companies also operated nonintegrated plants and/or other steelmaking facilities at the same locations.

Minimills and specialty mills are nonintegrated steel producers that use electric arc furnaces (EAFs) to melt low-cost raw materials (usually scrap). They also employ continuous casting machines and a hot-rolling mill that are often closely coupled to the casting operation. Specialty mills include producers of stainless, alloy-electrical, and tool steel; high-temperature alloys; forged ingots; and other low-volume steel products. The nonintegrated sector of the industry, 79 companies having 120 steelmaking plants, used the EAF steelmaking process to produce 47.8 Mt of steel, an increase of about 6% compared with that of 1999, and accounted for 47% of total steelmaking (American Iron and Steel Institute, 2000, p. 74; Iron and Steelmaker, 2001).

Raw liquid steel is mostly cast into semifinished products in continuous casting machines. Only 3.6% of U.S. production was cast in ingot form and subsequently rolled into semifinished forms; this represented a decrease of nearly 8% compared with that of 1999. Continuous casting production was 98.1 Mt, or 96.4% of total steel production, compared with 93.4 Mt, or 95.9%, in 1999 (American Iron and Steel Institute, 2000, p. 75).

Consumption

Steel mill products are produced at a steel mill either by forging or rolling into forms normally delivered for fabrication or use. Some companies purchase semifinished steel mill products from other steel companies and use them to produce finished steel products. To avoid double counting steel mill product shipments under these circumstances, steel mills identify any shipments of steel mill products to other companies that are reporters of steel mill product shipments. The accumulated shipments of all companies less the shipments to other reporting companies are identified as "net" shipments.

The 6-year trend of steadily increasing net shipments of steel products to satisfy domestic demand ended in 1998, but resumed its upward course in 1999 and 2000 (American Iron and Steel Institute, 2000, p. 27). Shipments of steel mill products by U.S. companies increased by 2.7%, to 98.9 Mt, compared with those of 1999. Export shipments by AISI reporting companies increased to 5.9 Mt from 4.9 Mt in 1999 (American Iron and Steel Institute, 2000, p. 45). Shipments to domestic customers increased by 2.3% during 2000 (American Iron and Steel Institute, 2000, p. 30). Shipments of construction and contractors' products, the largest single end-use market, increased 10%. Automotive product shipments decreased by 4.2%. Oil and gas, mining, quarrying, and lumbering industries shipments increased by 29%. Shipments of industrial and agricultural machinery, equipment, and tools decreased 8.4%. Steel service center shipments, appliance shipments, and containers, packaging, and shipping material shipments increased by 5.9%.

Prices

The Bureau of Labor Statistics Producer Price Index for steel mill products was up 3% to 108.4 from 105.3 in 1999 (1982 base=100) (Bureau of Labor Statistics, Producer Price Index-Commodities, accessed June 17, 2001, at URL http://146.142.4.24/cgi-bin/surveymost). The index increased steadily from about 105 throughout 1999 to a high of 110.2 in May 2000 and then decreased steadily to 105.5 at the end of 2000.

Foreign Trade

Exports of steel mill products increased to 5.9 Mt from 4.9 Mt in 1999 (American Iron and Steel Institute, 2000, p. 45). Canada again received the largest amount of U.S. exported steel, 3.8 Mt, up from 3.2 Mt in 1999. Mexico was again in second place, receiving 1.3 Mt, up from 1.1 Mt in 1999. Imports of steel mill products increased by 6.1% to 34.4 Mt from 32.4 Mt in 1999 (American Iron and Steel Institute, 2000, p. 55) . Brazil, Canada, the European Union (EU), Japan, the Republic of Korea, Mexico, and Russia were major sources of steel mill product imports.

Despite rising domestic steel mill capacity, imports of steel mill products have increased 140% since 1991 and imports of semifinished steel have nearly tripled. Domestic producers have been unable to keep up with demand for semifinished products and finished steel, and an unfavorable currency exchange rate has made foreign steel prices much more competitive. Although U.S. steelmakers have viewed imported finished steel as competing directly with domestic products, imports of semifinished products have not been perceived as rivals. This dichotomy is based on the need for imported semifinished steel to make up for the domestic shortage of hot-metal capacity to satisfy the U.S. market demand for finished steel mill products.

Imports of semifinished steel by steel companies must be taken into consideration in evaluating apparent consumption (supply) of steel mill products in the United States and the share of the market represented by imported steel. To avoid double counting the imported semifinished steel and the products produced from it, the amount of semifinished steel consumed by companies that also produced raw steel must be subtracted from domestic consumption. Between 1993 and 1998, annual imports were estimated to be 2.5 Mt to 7.8 Mt. Prior to 1993, the annual amount was less than 0.2 Mt. By taking the import semifinished steel into consideration, the share of the U.S. steel market represented by imported steel was an estimated 29% in 2000 compared with 28% in 1999.

Regarding the reporting of imports and exports, "fabricated steel products" are produced from steel mill products, but do not

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include products that incorporate steel products with other materials. Examples of fabricated steel products are fabricated structural steel and steel fasteners. "Other iron and steel products" refer to products that are not produced from steel mill products. Examples of other iron and steel products include iron or steel castings and direct reduced iron (DRI).

The year 1997 was the first time the AISI reported an indirect steel trade surplus since AISI began tracking the measurement in 1984. The measurement (comprising imports minus exports of steel-containing products by world areas and steel-consuming markets, expressed in metric tons of steel) accounts for virtually all products made with steel, such as automobiles, machine tools, and appliances. According to AISI, this surplus of 1.1 Mt, when compared with the 1986 indirect steel-trade deficit of 8.4 Mt, confirmed that in 1997 U.S. manufacturers were among the world's most competitive producers of high-quality, steel-containing goods. This surplus was followed by 3 years of increasing deficits—1.2 Mt, 4.7 Mt, and 5.8 Mt in 1998, 1999, and 2000, respectively.

World Review

World production of pig iron totaled about 571 Mt, 6.1% greater than that of 1999 (table 10). In Asia, China continued to be the leading producer of pig iron in the world, producing more than 131 Mt, a 4.8% increase from that of 1999. Japan and the United States followed with 81 Mt and 48 Mt, respectively. The Republic of Korea's production increased slightly. Russia and Ukraine were the only major pig iron producers in the Commonwealth of Independent States (CIS). Production in Russia increased by 9% since 1999 and was the highest in the past 5 years. During 2000, Ukrainian production continued a rising 5-year trend. In North America, the only major producer of pig iron was the United States, where production was 3% more than that of 1999. In South America, the only major pig iron producer was Brazil, producing nearly 28 Mt. Germany was the top producer in the EU producing about the same as in 1999. India's production increased by more than 6% of that of 1999.

DRI production worldwide was about 42 Mt, a 9% increase from that of 1999, and a 27% increase compared with that of 1996 (table 10). The leading technology was the Midrex process, followed by the HYL I and the HYL III processes. Because of the demand for charge materials and the growth of thin-slab casting, interest in DRI by steel producers continued to increase. The leading producer was Venezuela, followed by Mexico, India, and Iran (table 10). World capacity for DRI production was estimated to be nearly 52 million metric tons per year (Midrex Direct Reduction Corp., 2000). Additional DRI capacity of nearly 1.4 Mt was under construction in Iran and the Republic of Korea.

World production of crude steel exceeded 845 Mt, a 7.0% increase from the 789 Mt (revised) produced during 1999 (table 11). As in previous years, production varied widely among major regions of the world. Asian countries produced about 38% of the world's steel; the EU, 17%; and North America, 14%. During 2000, China was again the world's leading steel producer, exceeding 127 Mt, a gain of more than 2% compared with that of 1999. In descending order, the leading producers behind China were the United States, Japan, Russia, Germany, and the Republic of Korea. These six countries accounted for more than one-half of the world production. The combined steel production of the seven steel-producing countries in the CIS was over 98 Mt, an increase of nearly 18% compared with that of 1999. Russia and Ukraine remained the top producers, continuing to increase production over recent lows in 1998 (table 11).

Outlook

For 2001, the IISI forecast increasing world steel consumption of about 2.3% from that of 2000 (Steel Times International, 2000). The independent steel research unit, World Steel Dynamics, forecast that global demand for steel products will increase at a rate of 2.6% per year to 2010 (Kakela, 2000, p. 6). According to IISI, apparent consumption in the United States will decrease about 0.1%. Apparent consumption will increase, according to the IISI, in Brazil by 6.3%; the Republic of Korea, 4.7%; China, 7.3%; the EU, 0.4%; the CIS, 1.2%; and other Europe, 5.0%. Consumption will decrease in Japan by 0.7%. The IISI also predicted that by 2005 apparent consumption will increase more than that of 2001 in China, 3.8%; other Europe, 3%; the CIS, 2.8%; the EU, 0.8%; and North America, 0.9%. Consumption will decrease in Japan by 1%.

At the close of 2000, Government and industry economists and steel industry analysts were beginning to suspect that the record-breaking business expansion might be coming to an end. At the time of the Asian financial crisis of 1997-98, the U.S. economy was growing at a rate of about 5% per year and steel demand was very strong. By the end of 2000, the growth rate had declined by nearly one-half and demand for steel had diminished (Sacco, 2000). It was becoming increasingly apparent that the health of the domestic steel industry might improve, not by continuing to rely on antidumping trade laws, but by the consolidation of mills, especially the integrated mills, and even, perhaps, the minimills (Robertson, 2000). Large companies formed by the consolidation of small capitalization companies should be able to reduce overhead, achieve purchasing scale, eliminate unnecessary product duplication, and control pricing better while attracting investors to finance modernization. Only by closing inefficient capacity, reducing costs, adopting the latest steelmaking technology, and improving return on invested capital will these new companies become competitive with foreign mills. The industry would also need to decide whether it wants to produce less raw steel than domestic demand requires and continue to import supplementary quantities of semifinished steel to emphasize downstream product lines (Berry, 2001). To some observers, relinquishing significant raw steelmaking capacity to foreign countries by closing down coke ovens and blast furnaces raises national security concerns.

Minimills continued to improve efficiency and competitive capability, which supports the commonly held view that the EAF will eventually be the primary steel production method in the United States and the world. At least in the United States, blast furnaces will continue to face closure because of environmental restrictions, U.S. steelmakers are increasingly reluctant to make long-term maintenance expenditures on blast furnaces, and the EAF is more energy efficient and pollution free. Minimills cost less to build and operate, are more flexible in satisfying customer requirements, and satisfy the growing demand for recycling. Minimills will increase their efforts to conserve energy, which is about 75% less than for integrated mills. The minimills will increase usage of some form of iron—DRI, pig iron, hot metal—with the scrap charge to improve the quality of the steel they produce to serve broader

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markets. Thin slab casting in minimills eliminated the need for traditional hot-rolling facilities to reduce slab to hot-rolled sheet. Similarly, newly developing thin-strip casting may produce light-gauge sheet steel without several hot and cold reduction steps. This new technology will reduce the need for capital investment and will enable minimills to enter new markets.

References Cited

American Iron and Steel Institute, 2000, Annual report 2000: American Iron and Steel Institute, 128 p.

Berry, Bryan, 2001, Restructuring steel; New Steel, August, p. 2.

Bourge, Christian, 2001, EPA seeks tighter steel emission rules: American Metal Market, v. 109, no. 1, January 1, p. 1.

Iron & Steelmaker, 2000, Iron & Steelmaker's 2000 blast furnace roundup: Iron & Steelmaker, August, p. 38.

———2001, Iron & Steelmaker's 2000 EAF roundup: Iron & Steelmaker, May, p. 23.

Kakela, Peter, 2000, Base-load iron ore needs capital and innovations to elevate: Skillings Mining Review, v. 89, no. 49, December 2, p. 4-7.

Matthews, R.G., 2000, Too much steel, too few remedies: Wall Street Journal, October 23, p. A1.

Midrex Direct Reduction Corp., 2000, World direct reduction statistics: Midrex Direct Reduction Corp., p. 4.

Robertson, Scott, 2000, Consolidation likely to redraw mini-mill map: American Metal Market, v. 108, no. 122, June 26, p. 1.

Sacco, J.E., 2000, Rising imports, falling prices hurt steel: American Metal Market, v. 108, no. 219, November 13, p. 1.

Steel Times International, 2000, IISI expects renewed world steel consumption growth: Steel Times International, v. 24, no. 06, November, p. 33.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iron. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Iron and Steel. Ch. in Metal Prices in the United States Through 1998, 1999.

Iron and Steel. Ch. in Minerals Commodity Summaries, annual.

Iron and Steel. Ch. in Minerals Yearbook, annual.

Iron and Steel Scrap. Ch. in Metal Prices in the United States Through 1998, 1999.

Iron and Steel Scrap. Mineral Industry Surveys, monthly.

Iron and Steel Slag. Ch. in Minerals Commodity Summaries, annual.

Iron and Steel Slag. Ch. in Minerals Yearbook, annual.

Iron Ore. Ch. in Minerals Commodity Summaries, annual.

Iron Ore. Ch. in Minerals Yearbook, annual.

Iron Ore. Mineral Industry Surveys, monthly.

Other

American Metal Market, daily.

Annual Statistical Report, American Iron and Steel Institute, Washington, DC.

Directory of Iron and Steel Plants, Association of Iron and Steel Engineers, Pittsburgh, PA.

HYL, the Iron & Steel Technology Division of HYLSA, S.A. de C.V. HYL Report.

Iron and steel. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Iron and Steelmaker, American Institute of Mining, Metallurgical, and Petroleum Engineers—Iron and Steel Society, Warrenton, PA.

Making, Shaping, and Treating of Steel, Association of Iron and Steel Engineers, Pittsburgh, PA.

Metal Bulletin, biweekly.

Midrex Corporation. Direct from Midrex. Quarterly.

Steel Manufacturers Association, Washington, DC.

Steel Statistical Yearbook, International Iron and Steel Institute, Brussels, Belgium.

Steel Times International.

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TABLE 1
SALIENT IRON AND STEEL STATISTICS 1/

(Thousand metric tons)

	1996	1997	1998	1999	2000
United States:					
Pig iron:					
Production 2/	49,400	49,600	48,200	46,300	47,900
Exports 3/	60	86	87	82 r/	72
Imports for consumption 3/	2,660	3,150	5,140	4,990	4,970
Direct-reduced iron:					
Production 4/	450	510	1,600	1,670	1,560
Exports 3/	3	8	5	3	2
Imports for consumption 3/	1,050	987	939	950	988
Raw steel production: 5/					
Carbon steel	84,900	87,000	88,000	87,600	92,500
Stainless steel	1,870	2,160	2,010	2,190	2,190
All other alloy steel	8,710	9,290	8,600	7,650	7,510
Total	95,500	98,500	98,600	97,400	102,000
Capability utilization, percent	91	89	87	84	86
Steel mill products:					
Net shipments 2/	91,500	96,000	92,900	96,300	98,900
Exports 3/	4,560	5,470	5,010	4,920	5,920
Imports 3/	26,500	28,300	37,700	32,400	34,400
Producer price index for steel mill products (1982=100.0) 6/	115.6	116.4	113.8	105.3	108.4
World production: 7/					
Pig iron	516,000 r/	540,000 r/	534,000 r/	538,000 r/	571,000
Direct-reduced iron 4/	33,000 r/	36,200 r/	378,000 r/	38,000 r/	41,900
Raw steel	751,000	797,000	776,000	789,000 r/	846,000

NA Not available. r/ Revised.

1/ Data are rounded to three significant digits, except prices; may not add to totals shown.

2/ Data from American Iron and Steel Institute (AISI).

3/ Data from U.S. Census Bureau.

4/ Data from Midrex Direct Reduction Corp., government, and companies.

5/ Raw steel is defined by AISI as steel in the first solid state after melting, suitable for rolling.

6/ Data from Bureau of Labor Statistics.

7/ Data from U.S. Geological Survey and International Iron and Steel Institute.

TABLE 2
MATERIALS CONSUMED IN BLAST FURNACES AND PIG IRON PRODUCED 1/

(Thousand metric tons)

Material	1999	2000
Iron oxides: 2/		
Ores	645	345
Pellets	59,400	61,800
Sinter 3/	10,900	10,600
Total	70,900	72,800
Scrap 4/	1,550	1,470
Coke 2/	18,700	19,200
Pig iron produced	46,300	47,900

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ American Iron and Steel Institute.

3/ Includes sintered ore and pellet fines, dust, mill scale, and other revert iron-bearing materials; also some nodules.

4/ Mainly briquetted turnings and borings, shredded scrap, etc.; scrap produced at blast furnaces and remelt not included.

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TABLE 3
DISTRIBUTION OF SHIPMENTS OF STEEL MILL PRODUCTS, BY STEEL TYPE, PRODUCT, AND MARKET 1/

	Quantity (thousand metric tons)		Quantity (percentage)	
	1999	2000	1999	2000
Shipments by steel type:				
Carbon steel	89,500	92,100	92.9	93.1
Alloy steel	4,920	4,880	5.1	4.9
Stainless steel	1,890	1,930	2.0	1.9
Total	96,300	98,900	100.0	100.0
Steel mill products:				
Ingots, blooms, billets and slabs	1,020	1,220	1.06	1.24
Wire rods	4,750	4,420	4.94	4.47
Structural shapes-heavy	5,200	6,040	5.40	6.10
Steel piling	363	--	.38	--
Plates-cut lengths	4,530	5,100	4.70	5.16
Plates-in coils	2,910	2,990	3.02	3.02
Rails	454	593	.47	0.60
Railroad accessories	121	144	.13	0.15
Bars, hot-rolled	7,160	6,990	7.44	7.07
Bars, light-shaped	2,140	1,410	2.22	1.43
Bars, reinforcing	5,940	6,270	6.16	6.33
Bars, cold finished	1,640	1,580	1.70	1.60
Tool steel	48	41	.05	0.04
Pipe and tubing-standard pipe	1,140	1,210	1.18	1.22
Pipe and tubing-oil country goods	895	1,620	.93	1.64
Pipe and tubing-line pipe	1,230	885	1.27	0.89
Pipe and tubing-mechanical tubing	885	943	.92	0.95
Pipe and tubing-pressure tubing	20	34	.02	0.03
Pipe and tubing-stainless	19	15	.02	0.02
Pipe and tubing-structural	108	136	.11	0.14
Pipe for piling	44	36	.05	0.04
Wire	579	526	.60	0.53
Tin mill products-blackplate	210	285	.22	0.29
Tin mill products-tinplate	2,370	2,290	2.46	2.31
Tin mill products-tin-free steel	747	739	.78	0.75
Tin mill products-tin coated sheets	90	82	.09	0.08
Sheets, hot-rolled	16,900	17,900	17.60	18.13
Sheets, cold-rolled	12,700	13,500	13.17	13.62
Sheets, and strip hot dip galvanized	13,500	13,500	14.01	13.64
Sheets, and strip electrogalvanized	3,420	3,170	3.55	3.21
Sheets, and strip other metallic coated	1,910	1,940	1.98	1.96
Sheets, and strip electrical	510	480	.53	0.49
Strip, hot rolled	890	788	.92	0.80
Strip, cold rolled	1,860	2,050	1.93	2.07
Total	96,300	98,900	100.00	100.00
Shipments by markets:				
Service centers and distributors	25,500	27,300	26.45	27.61
Construction	16,700	18,400	17.35	18.61
Automotive	15,200	14,600	15.79	14.73
Machinery	1,560	1,620	1.62	1.64
Containers	3,490	3,360	3.62	3.40
All others	33,900	33,600	35.17	34.02
Total	96,300	98,900	100.00	100.00

-- Zero.

1/ Data are rounded to no more than three significant digits, except percentages; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 4
U.S. IMPORTS AND EXPORTS OF STEEL MILL PRODUCTS, BY COUNTRY 1/

(Thousand metric tons)

Country	1999		2000	
	Imports	Exports	Imports	Exports
Argentina	437	8	417	4
Australia	850	6	737	5
Brazil	3,440	10	3,280	16
Canada	4,570	3,230	4,770	3,790
China	698	24	1,350	24
European Union	6,010	201	6,400	281
Finland	222	1	--	1
Japan	2,780	9	1,930	14
Korea, Republic of	2,670	11	2,430	20
Mexico	3,190	1,050	2,950	1,350
Russia	1,140	--	1,370	--
South Africa	535	3	585	3
Sweden	183	2	175	1
Taiwan	876	8	1,150	12
Turkey	364	--	609	--
Ukraine	713	--	1,410	--
Venezuela	468	24	433	30
Other	3,260	333	4,430	375
Total	32,400	4,920	34,400	5,920

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 5
U.S. EXPORTS OF IRON AND STEEL PRODUCTS 1/

(Thousand metric tons)

	1999	2000
Steel mill products:		
Ingots, blooms, billets, slabs	125	102
Wire rods	63	58
Structural shapes-heavy	376	346
Steel piling	14	25
Plates-cut lengths	371	466
Plates-in coils	207	401
Rails-standard	14	28
Rails-other	10	6
Railroad accessories	12	15
Bars, hot-rolled	343	386
Bars, light-shaped	101	104
Bars, concrete reinforcing	116	117
Bars, cold-finished	99	118
Tool steel	12	9
Pipe and tubing-standard pipe	59	74
Pipe and tubing-oil country goods	142	157
Pipe and tubing-line pipe	173	161
Pipe and tubing-mechanical tubing	5	5
Pipe and tubing-stainless	27	37
Pipe and tubing-nonclassified	293	341
Pipe and tubing-structural	82	116
Pipe for piling	4	3
Wire	149	146
Tin mill products-blackplate	11	5
Tin mill products-tinplate	265	289
Tin mill products-tin-free steel	30	47
Sheets, hot-rolled	337	448
Sheets, cold-rolled	502	638
Sheets, and strip-hot-dip galvanized	252	417
Sheets, and strip-electrogalvanized	199	262
Sheets, and strip-other metallic coated	144	155
Sheets, and strip-electrical	74	60
Strip, hot-rolled	87	102
Strip, cold-rolled	223	278
Total	4,920	5,920
Fabricated steel products:		
Structural shapes-fabricated	263	244
Rails-used	26	33
Railroad products	63	48
Wire rope	13	14
Wire-stranded products	40	41
Wire-other products	18	51
Springs	110	96
Nails and staples	31	28
Fasteners	423	339
Chains and parts	24	27
Grinding balls	19	33
Pipe and tube fittings	32	33
Other 2/	56	61
Total	1,120	1,050
Grand total	6,040	6,970
Cast iron and steel products:		
Cast steel pipe fittings	32	33
Cast iron pipe and fittings	73	65
Cast steel rolls	15	18
Cast grinding balls	17	12
Granules-shot and grit	27	29
Other castings	39	45
Total	203	202

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes shapes-cold formed, sashes and frames, fence and sign post, and architectural and ornamental work, and conduit.

Source: American Iron and Steel Institute.

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TABLE 6
U.S. IMPORTS OF MAJOR IRON AND STEEL PRODUCTS 1/

(Thousand metric tons)

	1999	2000
Steel mill products:		
Ingots, blooms, billets and slabs	7,780	7,760
Wire rods	2,510	2,700
Structural shapes-heavy	1,290	1,760
Steel piling	118	182
Plates-cut lengths	829	897
Plates-in coils	1,440	1,410
Rails and railroad accessories	258	249
Bars, hot-rolled	1,360	1,580
Bars, light-shaped	265	319
Bars, reinforcing	1,660	1,520
Bars, cold-finished	277	373
Tool steel	149	162
Pipe and tubing-standard pipe	777	1,160
Pipe and tubing-oil country goods	154	653
Pipe and tubing-line pipe	842	809
Pipe and tubing-mechanical tubing	399	510
Pipe and tubing-pressure tubing	47	51
Pipe and tubing-stainless	76	88
Pipe and tubing-nonclassified	25	25
Pipe and tubing-structural	431	476
Pipe for piling	19	34
Wire	670	669
Tin mill products-blackplate	151	131
Tin mill products-tinplate	447	359
Tin mill products-tin-free steel	186	167
Sheets, hot-rolled	4,500	5,360
Sheets, cold-rolled	3,100	2,630
Sheets, and strip-hot-dip galvanized	1,910	1,590
Sheets, and strip-electrogalvanized	171	236
Sheets, and strip-other metallic coated	209	237
Sheets, and strip-electrical	104	111
Strip, hot-rolled	73	59
Strip, cold-rolled	181	165
Total	32,400	34,400
Fabricated steel products:		
Structural shapes-fabricated	532	639
Rails-used	348	271
Railroad products	115	102
Wire rope	104	100
Wire-stranded products	172	179
Springs	517	523
Nails and staples	545	573
Fasteners	1,030	1,170
Chains and parts	95	99
Pipe and tube fittings	125	148
Other	439	436
Total	4,020	4,240
Grand total	36,400	38,700
Cast iron and steel products:		
Cast steel pipe fittings	125	148
Cast iron pipe and fittings	42	40
Other products	338	369
Total	505	557

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 7
U.S. IMPORTS OF STAINLESS STEEL 1/

(Metric tons)

Product	1999	2000
Semifinished	313,000	312,000
Plate	68,100	74,200
Sheet and strip	72,500	55,500
Bars and shapes	86,800	126,000
Wire and wire rods	79,800	102,000
Pipe and tube	75,600	87,700
Total	696,000	757,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

TABLE 8
U.S. SHIPMENTS OF IRON AND STEEL CASTINGS 1/

(Thousand metric tons)

	1999	2000
Ductile iron castings	4,230	4,140
Gray iron castings	5,400	5,220
Malleable iron castings	188	169
Steel castings	1,090	943
Steel investment castings	69	78
Total	11,000	10,600

1/ Data are rounded to no more than three significant digits; may not add to totals shown

Source: U.S. Census Bureau.

TABLE 9
COAL AND COKE AT COKE PLANTS 1/ 2/

(Thousand metric tons)

	1999	2000
Coal, consumption	25,500	26,600
Coke: 3/		
Production	18,200	19,100
Exports	814	1,040
Imports	2,920	3,430
Consumption, apparent	20,300	21,300

1/ Data are rounded to no more than three significant digits.
2/ Includes furnace and merchant coke plants.
3/ Coke production and consumption do not include breeze.

Source: Energy Information Administration, Quarterly Coal Report, DOE/EIA-0121 (2000/4Q

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TABLE 10
PIG IRON AND DIRECT-REDUCED IRON: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/ 4/

(Thousand metric tons)

Country 5/	1996	1997	1998	1999	2000
Albania e/	10	10	10	10	10
Algeria e/	800	700	700	500	500
Argentina:					
Pig iron	1,966	2,080 r/	2,122 r/	1,985 r/	2,188 p/
Direct-reduced iron	1,422	1,496 r/	1,538	989 r/	1,420 p/
Australia	7,774	7,884	7,724	7,468 r/	7,000 e/
Austria	3,416	3,965	4,022	3,913	4,318
Belgium	8,628	8,077	8,730	8,472	8,472
Bosnia and Herzegovina e/	100	100	100	100	100
Brazil:					
Pig iron	23,978	25,013	25,111	25,060	27,723
Direct-reduced iron	335	323	336	400	418
Bulgaria	1,513	1,644	1,389	1,130	1,220
Burma:					
Pig iron	1	--	2	2	2
Direct-reduced iron	40	40	40 e/	40	40
Canada:					
Pig iron	8,638	8,670	8,937	8,783	8,904
Direct-reduced iron	1,420	1,390	1,240	920	1,130
Chile	996	941	993	1,033	1,026
China 6/	107,225	115,110	118,600	125,390	131,030
Colombia	286 r/	324 r/	256	264 r/	285
Czech Republic	4,898	5,195	4,982	4,022	4,621
Egypt:					
Pig iron e/	1,050	1,000	1,334 r/ 7/	700 r/	700
Direct-reduced iron	827 r/	1,190	1,610	1,670	1,530
Finland	2,457	2,786 r/	2,912 r/	2,954	2,983
France	12,108	13,424	13,603	13,854	13,621
Germany:					
Pig iron	30,012	30,939	30,162	27,931	30,846
Direct-reduced iron	370	470	450	400	400 e/
Hungary	1,496	1,141	1,258	1,309	1,340
India:					
Pig iron	19,864	19,898	20,194	20,139	21,321
Direct-reduced iron	4,830	5,250	5,260	5,220	5,440
Indonesia, direct-reduced iron e/	1,800	1,600	1,400	1,500	1,740
Iran:					
Pig iron	1,867	2,053	2,087 r/	2,147 r/	2,202
Direct-reduced iron	3,778	4,380	3,690	4,120	4,740
Italy	10,347	11,348	10,704	10,509	11,223
Japan	74,597	78,519	74,981	74,520	81,071
Kazakhstan	2,536	3,040	2,594	3,438	4,000
Korea, North e/	500	500	250	250	250
Korea, Republic of	23,010	22,712	23,229	23,329	24,937
Libya: Direct-reduced iron	862	990	1,200	1,330 r/	1,500 e/
Luxembourg 8/	829	437	--	--	--
Macedonia e/	20	--	--	--	--
Malaysia, direct-reduced iron e/	1,049 7/	1,720	1,700 r/	1,000 r/	1,200
Mexico:					
Pig iron	4,229	4,450	4,532	4,808 r/	4,856
Direct-reduced iron	3,794	4,440	5,584	6,070 r/	5,589
Morocco e/	15	15	15	15	15
Netherlands 8/	5,545	5,804	5,561	5,320	4,969
New Zealand	619	534	609	620	600 e/
Nigeria, direct-reduced iron e/	20	--	--	--	-- 7/
Norway e/	70	70	70	60	60
Pakistan e/	1,500	1,400	1,500	1,500	1,500
Paraguay	104	79 r/	66	61 r/	82
Peru:					
Pig iron	273	264	283	237	327
Direct-reduced iron	22	120	110	50	80
Poland	6,581	7,296	6,128	6,128	6,492
Portugal	421	431	365	389	382

See footnotes at end of table.

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TABLE 10--Continued
PIG IRON AND DIRECT-REDUCED IRON: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/ 4/

(Thousand metric tons)

Country 5/	1996	1997	1998	1999	2000
Qatar, direct-reduced iron	632	570	706	670	620
Romania	4,025	4,557	4,541	2,969 r/	3,069
Russia:					
Pig iron	36,061	37,327	34,827	40,854 r/	44,618
Direct-reduced iron	1,500	1,730 e/	1,550	1,880	1,900 e/
Saudi Arabia, direct-reduced iron	2,296	2,110	2,268	2,343	3,090
Serbia and Montenegro	535	907	826	135	563
Slovakia	3,300 e/	3,072	2,756	2,987	3,000 e/
South Africa:					
Pig iron	6,876	6,192	5,650	4,587	4,573
Direct-reduced iron	900	1,120 r/	1,070	1,260 r/	1,530
Spain	4,128	3,926	4,278	4,146	4,059
Sweden	3,255	3,060	3,373	3,212	3,146
Switzerland e/	100	100	100	100	100
Taiwan	6,050	8,870	9,374	9,020 r/	10,927
Trinidad and Tobago, direct-reduced iron	954	1,140	1,073	1,379	1,530
Tunisia	145	153	123 r/	178	192
Turkey	490 r/	577 r/	456 r/	315 r/	300
Ukraine	18,143	20,561	20,840	21,937	25,700
United Kingdom	12,830	13,057	12,574	12,399	10,989
United States:					
Pig iron	49,400	49,600	48,200	46,300	47,900
Direct-reduced iron	450	510	1,600	1,670	1,560
Venezuela, direct-reduced iron	5,732 r/	5,608 r/	5,424 r/	5,071 r/	6,412
Zimbabwe e/	210	216	217	228	240
Grand total	549,000 r/	576,000 r/	572,000 r/	576,000 r/	612,000
Of which:					
Pig iron	516,000 r/	540,000 r/	534,000 r/	538,000 r/	571,000
Direct-reduced iron	33,000 r/	36,200 r/	37,800 r/	38,000 r/	41,900

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Production is pig iron unless otherwise specified.

3/ Direct-reduced iron is obtained from ore by reduction of oxides to metal without melting.

4/ Table excludes ferroalloy production except where otherwise noted. Table includes data available through August 2, 2001.

5/ In addition to the countries listed, Vietnam has facilities to produce pig iron and may have produced limited quantities during 1996-2000, but output is not reported and available information is inadequate to make reliable estimates of output levels.

6/ Figures reported by State Statistical Bureau that the Chinese Government considers as official statistical data.

7/ Reported figure.

8/ Includes blast furnace ferroalloys.

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TABLE 11
RAW STEEL: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/

(Thousand metric tons)

Country 4/	1996	1997	1998	1999	2000
Albania e/	20	20	15	15	180
Algeria	620	427	400 e/	400 e/	400
Angola e/	9	9	9	9	9
Argentina	4,075 r/	4,169 r/	4,216 r/	3,805 r/	4,474
Australia	8,415	8,769	8,798	8,158	7,812
Austria	4,442	5,196	5,298	5,213 r/	5,725
Azerbaijan	25	25	24 e/	25 e/	25
Bangladesh e/ 5/	37	36	35	36	35
Belarus	886 e/	1,220	1,299	1,345	1,500
Belgium	10,773	10,738	11,427	10,972	11,637
Bosnia and Herzegovina e/	115	115	115	150	150
Brazil 6/	25,237	26,153	25,760	24,996	27,752
Bulgaria	2,457	2,628	2,216	1,846	1,900
Burma e/	40 7/	-- 7/	24	24	24
Canada	14,735	15,554	15,930	16,300	16,500 e/
Chile 6/	1,178	1,167	1,171	1,291 r/	1,352
China 8/	101,241	108,940	115,590	124,260	127,240
Colombia	695 r/	734 r/	636 r/	534 r/	660
Croatia	46	69	105	77	68
Cuba	231 r/	342	283 r/	303 r/	336
Czech Republic	6,257	6,495	6,498	5,613	5,700
Denmark	737	787	790	748	783
Dominican Republic	42 r/	82 r/	36 r/	43 r/	36
Ecuador	20	44	46	53	65
Egypt	2,618	2,717	2,870 r/	2,619	2,820 e/
El Salvador	41 r/	45 r/	43 r/	34 r/	41
Finland	3,301	3,687	3,932 r/	3,956	4,096
France	17,630	19,773	20,126	20,211	20,980
Georgia	85	104	50 r/ e/	100 r/ e/	-- 9/
Germany	39,791	45,009	44,046	42,056	46,376
Greece	848	1,016	1,109	951	1,056
Guatemala	--	--	--	--	152 p/
Hong Kong e/	350	350	350	450	500
Hungary	1,969	1,829	1,821	1,813	1,871
India	23,753	23,748	23,480	24,269	26,924
Indonesia e/	4,100	3,800	2,700	2,890 r/	3,010
Iran	5,415	6,322	5,608 r/	6,070 r/	6,600
Iraq e/	300	200	200	200 r/	200
Ireland	340	337	358	335 r/	375
Israel e/	246 r/	268 r/	244 r/	280 r/	285
Italy	23,922	25,537	25,798	24,964	26,544
Japan	98,801	104,545	93,548	94,192 r/	106,444
Jordan	30 e/	--	--	-- e/	--
Kazakhstan	3,142	3,900	3,089	4,116	4,770
Kenya e/	30	33	25	25	25
Korea, North e/	1,500	1,000	1,000	1,000	1,000
Korea, Republic of	38,903	42,554	39,896	41,042	43,107
Latvia	293	465 r/	469 r/	484 r/	500
Libya	863 e/	897	925 r/	945	1,055
Luxembourg	2,501	2,580	2,592	2,477	2,571
Macedonia	27	30 e/	--	-- e/	--
Malaysia	3,216	2,962	1,921 r/	2,200 r/	2,430
Mexico	13,172 r/	14,218 r/	14,182 r/	15,243 r/	15,659
Moldova	646	810	718	796	905
Morocco e/	5	5	5	5	5
Netherlands	6,325	6,640	6,379	6,075	5,667
New Zealand	680	680	756	744	765
Nigeria e/	--	--	2	--	--
Norway	511	570	644	611	620
Pakistan	416	479	494	500 e/	500 e/
Paraguay	96	66	56	56 r/	77
Peru	678	607	631	559 r/	749
Philippines	920	950	880 r/	530 r/	530 e/

See footnotes at end of table.

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TABLE 11--Continued
RAW STEEL: WORLD PRODUCTION, BY COUNTRY 1/ 2/ 3/

(Thousand metric tons)

Country 4/	1996	1997	1998	1999	2000
Poland	10,433	11,585	9,915	8,853 r/	10,498
Portugal	871	905	854	1,044 r/	1,060
Qatar	626 r/	616 r/	646 r/	629	729
Romania	6,083	6,674	6,335	4,392 r/	4,770
Russia	49,193	48,499	43,822	51,524 r/	59,098
Saudi Arabia	2,683	2,539	2,356	2,610	2,973
Serbia and Montenegro	679	979	949	226	682
Singapore e/	500	500	500	500	500
Slovakia	3,602	3,835	3,428	3,569	3,600
Slovenia	328	373	405	405	450
South Africa	7,999	8,311	7,506	6,830 r/	7,019
Spain	12,036	13,644	14,827 r/	14,886 r/	15,920
Sri Lanka e/	30	30	30	30	30
Sweden	4,910	5,147	5,062 r/	5,075	5,227
Switzerland	854 r/	1,047 r/	1,018 r/	1,037 r/	1,140
Syria e/	70	70	70	70	70
Taiwan	12,650	15,478	17,192	16,027	17,302
Thailand	2,143	2,101	1,814 r/	1,547 r/	2,100
Trinidad and Tobago	695	736	777 r/	729 r/	741
Tunisia	187	195	171	229	237
Turkey	13,382	13,664	13,351	14,309	14,325
Uganda e/	12	15	15	15	7 7/
Ukraine	22,100	25,600	23,461	27,390 r/	31,780
United Kingdom	18,220	18,528	17,066	16,634	15,022
United States	95,500	98,500	98,600	97,400	102,000
Uruguay	34	39	52	45 r/	38
Uzbekistan	444	365	344	343 e/	420
Venezuela	3,956 r/	3,987 r/	3,553 r/	3,261 r/	3,835
Vietnam	311	314	306 r/	308 r/	306
Zimbabwe e/	212	214	212	255 r/	269
Total	751,000	797,000	776,000	789,000 r/	846,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Steel formed in solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

3/ Table includes data available through August 2, 2001.

4/ In addition to the countries listed, Ghana and Mozambique are known to have steelmaking plants, but available information is inadequate to make reliable estimates of output levels.

5/ Data for year ending June 30 of that stated.

6/ Excludes castings.

7/ Reported figure.

8/ Figures reported by State Statistical Bureau that Chinese Government considers as official statistical data.

9/ Production appears to have sharply curtailed or to have ceased.

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IRON AND STEEL SCRAP

By Michael D. Fenton

Domestic survey data and tables were prepared by David Gibson, statistical assistant.

Iron and steel scrap is a vital raw material for the production of new steel and cast-iron products. The steelmaking and foundry industries in the United States are highly dependent upon the ready availability of scrap from manufacturing operations and from the recovery of products that are no longer used or needed. The steel industry has been recycling steel scrap for more than 150 years. In 2000, domestic electric-arc-furnace (EAF) steel made primarily from recycled ferrous scrap in about 41 minimills was 47% of the total steel produced. Consistent with international usage and Federal Government policy, the U.S. Geological Survey (USGS) reports all data on iron and steel in metric units, unless otherwise noted.

Steel scrap recycling conserves raw materials, energy, and landfill space. The domestic steel industry recycles millions of metric tons per year of steel cans, automobiles, appliances, construction materials, and other steel products. In 2000, the industry's overall recycling rate was 64% (Steel Recycling Institute, [undated], A few facts about steel—North America's #1 recycled material, accessed May 11, 2001, at URL http://www.recycle-steel.org/fact/main.html). The remelting of scrap requires much less energy than the production of iron and steel products from iron ore. Each year, steel recycling saves the energy equivalent of the electrical power needed for 1 year by approximately one-fifth of the houses in the United States (about 18 million). Consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment. Every metric ton of steel recycled saves about 1.3 metric tons (t) of iron ore, 700 kilograms (kg) of coal, and 60 kg of limestone that would be needed to make a ton of steel from new raw materials.

In the United States, the primary source of obsolete steel is the automobile (Steel Recycling Institute, [undated], Recycling scrapped automobiles, accessed June 9, 1999, at URL http://www.recycle-steel.org/cars/autorec.html). Of the ferrous metals used to make a typical 2000 U.S. family vehicle, 45% was recycled metal. About 16,000 car dismantlers and 3,000 scrap processors produced about 12.7 million metric tons (Mt) of iron and steel scrap for recycling in 2000—enough steel to produce over 14 million new cars. The recycling rate of automobile scrap steel exceeded 95% in 2000 compared with 91% in 1999.

The recycling rate of obsolete appliance scrap had increased from 20% in 1988 to 81% in 1997, decreased to 72% in 1998, and rebounded to 84% in 2000. During 2000, more than 2.0 Mt of steel were recovered from recycled appliances (Steel Recycling Institute, [undated], A few facts about steel—North America's #1 recycled material, accessed May 6, 2000, at URL http://www.recycle-steel.org/fact/main.html). The typical appliance consists of about 75% steel, and from 25% to 100% of the steel used in appliances is recycled. The recycling rate of steel cans increased to 61% in 1997 from 15% in 1988, decreased to 56% in 1998, and rebounded to over 58% in 2000. The estimated rate of recycling of structural beams and plates in 2000 was 95% and that of reinforcement bar and other materials was 48%. By 2002, an estimated 25% of all new homes built in the United States will be framed in recycled steel.

Minimills in which EAFs are used consumed greater quantities of direct reduced iron (DRI) to improve steel quality, and integrated steelmakers continued to use small quantities of DRI in blast furnaces as a process coolant. Mills often used a feed mix that has equal proportions of DRI, pig iron, and scrap. Although production in the U.S. steel industry increased during 2000, DRI production decreased by 6.6%.

The U.S. steel industry was adversely affected by the 1997 Asian financial crisis as Asian demand for steel and ferrous scrap declined, Asian currency exchange rates declined, and inexpensive steel became available for export to U.S. markets from excess Asian steel-producing capacity. Domestic steel product manufacturers welcomed inexpensive imports, but domestic steel producers were forced to reduce production and scrap consumption, which led to an oversupply of scrap and a plunge of scrap prices to the lowest levels in decades. By early 1999, the steel-producing and scrap industries were on the rebound owing primarily to resurging Asian economies and increasing steel demand in Asia and the United States.

As 2000 began, steel producers and scrap suppliers were increasingly optimistic that they were on track for a slow but certain recovery to precrisis economic levels. However, to the detriment of these sectors, the U.S. economic expansion—the longest in U.S. history—was showing signs of weakening. Concurrently, prices of electricity and natural gas were increasing significantly, and steel imports, which declined in 1999 below the 1998 level, began to increase again in 2000. Prices for steel products and ferrous scrap again plunged to record levels. Although for relief the U.S. steel industry filed trade cases against allegedly dumped hot-rolled carbon steel from 11 countries, it was becoming clear that a more fundamental problem was that the world and the United States had excess steelmaking capacity (Iron and Steelmaker, 2001; Matthews, 2001). Steelmakers had the capacity to produce 15% more steel than the world market demand in 2000, but were adding capacity at the rate of 2% each year.

Environment

In 1997, the U.S. Department of Energy (DOE) contracted to decommission and decontaminate three uranium enrichment plants at DOE's Oak Ridge, TN, nuclear reservation, which contained an estimated 100,000 t of radioactive metals (Paper, Allied-Industrial, Chemical and Energy Workers Union, [undated], Court finds that energy department plan to recycle radioactive metals from nuclear weapons factories poses great potential for environmental harm, accessed July 7, 1999, at URL http://biz.yahoo.com/prnews/990630/dc_court_e_2.html). DOE arranged to sell 6,000 t of contaminated nickel from a former nuclear weapons plant (American Metal Market, 2000a).

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The Metals Industry Recycling Coalition, which consists of steel, nickel, zinc, copper and brass interests, lobbied to prevent radioactive-contaminated scrap from reaching the commerce stream. Their concern was that consumers would reject recycled goods made from radioactive scrap even if the level of radiation was deemed to be safe by the Government. At yearend 2000, the DOE issued a memorandum recommending the preparation of a full environmental impact statement on the proposed rulemaking governing the release of radioactive metal. The effect was to delay the release of radioactive metal into the commerce stream.

In addition to the radioactive materials, other potentially hazardous materials used in vehicles and durable goods are entering the recycling system (Wiener, 2001). Mercury switches have been suspected as contributors to high mercury readings in recent electric furnace stack tests. Steel air-bag inflators are sealed units that may deploy and injure employees sorting scrap and working in steel mill melt shops. Also, the propellant in the inflators, sodium azide, can be potentially hazardous to the environment. Substitution of mercury switches with pressure switches by vehicle manufacturers and removal of mercury switches and air bag inflators by dismantlers prior to shredding would ensure that injury to employees and the environment do not occur.

In July 1997, the U.S. Environmental Protection Agency (EPA) revised the National Ambient Air Quality Standards for particulate matter (PM), which met resistance by the steel industry. The EPA reduced the standard for airborne PM from 10 microns to 2.5 microns (U.S. Environmental Protection Agency, 1998). The American Iron and Steel Institute and several other business groups initiated litigation against the EPA, and a three-judge panel of the U.S. Circuit Court of Appeals for the District of Columbia ruled that the agency overstepped its authority by interpreting the 1990 Clean Air Act so loosely that it unlawfully usurped Congress' legislative power. The full appeals court voted in October 1999 against reviewing the panel's decision (New Steel, 1999). Later, in May 2000, the Supreme Court entered the dispute by announcing that they will decide whether antipollution regulations must take the costs of compliance, not just health effects, into account. If the Court rules in favor of such cost-benefit analyses, allegedly unneeded and unfeasible air-quality standards might not be required of the steel industry, among others (Washington Times, 2000a).

Consumption

Domestic data for ferrous scrap were derived from voluntary monthly or annual surveys of U.S. scrap consuming operations by the USGS. About 45% of the known manufacturers of pig iron and raw steel responded to the surveys. Their responses represented about 59% of estimated total scrap consumption by this class of consumers. The remaining 41% of scrap consumption was estimated on the basis of prior reports. For manufacturers of steel castings, iron foundries, and miscellaneous users, about 31% of the surveyed establishments, which represented about 46% of estimated scrap consumption by these consumers, responded to the annual survey. Total consumption for these two classes of consumers was estimated by using statistical methods and prior reports. Actual survey data accounted for about 44% of total estimated scrap consumption by all classes of scrap consumers.

In 2000, brokers, dealers, and other outside sources supplied domestic consumers with 54 Mt of all types of ferrous scrap at an estimated delivered value of more than $5.2 billion and exported 5.8 Mt (excluding used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) valued at $1.0 billion (tables 1, 8, 11). In 1999, domestic consumers received 51 Mt of scrap at an estimated delivered value of about $4.8 billion; exports totaled 5.5 Mt valued at $758 million. This represented a tonnage increase during 2000 of nearly 6% for received quantities and over 4% for exported quantities. The total value of received and exported scrap grades increased 13% from that of 1999.

Raw steel production was 101.8 Mt in 2000 compared with 97.4 Mt in 1999 (American Iron and Steel Institute, 2000, p. 75). The shares of raw steel produced by electric and basic oxygen furnaces were 47% and 53%, respectively; EAF production increased slightly during 2000. In 2000, continuous cast steel production represented 96% of total raw steel production, as it had in 1999. Raw steel production capability was 118 Mt compared with 116 Mt in 1999.

Steel mills accounted for 84% of all scrap received from brokers, dealers, and other outside sources; iron foundries and miscellaneous users received 14%; and steel foundries received 2% (table 2). Apparent total domestic consumption of ferrous scrap was 54 Mt of net receipts (total receipts minus shipments) and 20 Mt of home scrap (table 1). Stocks of ferrous scrap at consumers' plants decreased by nearly 4% to 5.3 Mt (table 1). Total domestic consumption was about 74 Mt, a 4% increase since 1999 (table 1). The total market for U.S.-produced scrap (net receipts plus exports minus imports) was 56.5 Mt compared with 53.3 Mt in 1999. Feedstock used in electric furnaces by all iron and steel product manufacturers comprised scrap, 91%; pig iron, 5.3%; and DRI, 3.4% (table 4). Consumption of DRI was 11% greater than that of 1999.

Net shipments of all grades of steel mill products were 98.9 Mt, which was an increase of 2.7% from the 96.3 Mt shipped in 1999 (American Iron and Steel Institute, 2000, p. 27). Imports of steel mill products increased to 34.4 Mt from 32.4 Mt in 1999. Exports of steel mill products increased to 5.9 Mt from 4.9 Mt in 1999 (American Iron and Steel Institute, 2000, p. 45). The U.S. apparent supply of steel mill products increased to 120 Mt from 116 Mt in 1999. As a share of the U.S. market, imports of steel mill products increased to 29% from 28% in 1999. Pig iron production increased to 47.9 Mt from 46.3 Mt in 1999 (American Iron and Steel Institute, 2000, p. 80). As reported by the U.S. Census Bureau, iron castings shipments totaled an estimated 9.9 Mt for 1999 and 9.9 Mt (revised) for 1998. Steel castings shipments (including investment castings) totaled 1.2 Mt in 1999, the same as in 1998.

Transportation

In June 1999, the acquisition of Conrail, Inc by CSX Transportation, Inc. (42%) and Norfolk Southern Corp. (58%) reduced the number of large rail carriers from 3 to 2 in 23 States east of the Mississippi River, the District of Columbia, Quebec, and Ontario. The railroad system is the main form of transportation of ferrous scrap in the United States. A significant part of the industry experienced considerable deterioration of service, such as train backups, routing problems, lost cars and billing, erroneous information given to shippers, car unavailability, and mistakenly routed shipments.

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These problems were based, for the most part, on the railroads' difficulty in integrating the computer systems of the merged railroads. All of this resulted in canceled contracts, smaller orders, and increased costs (American Metal Market, 1999, 2000b). One year later, the general opinion was that the railroads are performing much better (Robertson, 2000). The railroads invested in new track capacity in the Midwest, new terminal capacity in Buffalo, NY, and improvements at railyards throughout the Northeast and the Midwest. They also installed improved computer systems while working closely with shippers to solve delivery problems.

The Surface Transportation Board of the Federal Government ordered in March a moratorium on new consolidations in the railroad industry while it develops new rules for mergers. It was concerned about problems for shippers resulting from recent railroad mergers (Washington Times, 2000b). The steel industry, among others, expressed its opposition to more railroad consolidation because it no longer has an affordable option to choose truck transportation over rail transportation, given recent fuel price increases (American Metal Market, 2000c).

Prices

The average composite delivered price per metric ton of No. 1 heavy-melting steel scrap, calculated from prices per long ton published monthly by American Metal Market, was $95.88. The price ranged from a high of $120.06 in January to a low of $77.36 in December (table 8). The average composite delivered price per ton of No. 1 heavy-melting steel scrap, calculated from prices per long ton published weekly in Iron Age Scrap Price Bulletin, was $92.61; the price had ranged from a high of $112.07 in January to a low of $73.27 in November.

On the basis of weekly quotations by Iron Age Scrap Price Bulletin for 18-8 (18% chromium, 8% nickel) stainless steel scrap (bundles and solids) delivered to consumers in the Pittsburgh, PA, area, the average price increased by 32% to $823 per metric ton from $624 in 1999.

The unit value of total ferrous scrap exports (excluding used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) increased by about 30% to about $174 per metric ton compared with that of 1999 (table 11). The unit value of total imports, about $85 per ton, was about 18% less than that of 1999 (table 14).

Foreign Trade

Foreign trade valuation continued to be reported on a free-alongside-ship (f.a.s.) basis for exports and on a Customs value basis for imports. In 2000, the U.S. trade surplus for all classes of ferrous scrap (including used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) was 2.2 Mt valued at $597 million (U.S. Census Bureau, unpub. data, 2000). This represented an increase of 42% in quantity and 82% in value compared with the 1999 surpluses of 1.5 Mt and $328 million.

Total U.S. exports of carbon steel and cast-iron scrap (including reexports and excluding used rails for rerolling and other uses; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) went to 55 countries (1 less than during 1999) and totaled 4.5 Mt (a 4% decrease) valued at $526 million (an 11% increase) for an average of $116 per ton (U.S. Census Bureau, unpub. data, 2000). The largest tonnages went to the Republic of Korea, 1.24 million; Canada, 1.04 million; Mexico, 792,000; China, 773,000; and Taiwan, 205,000. These countries received 90% of the total quantity valued at $451 million, which was 86% of the total value.

Total U.S. exports of stainless steel scrap, including reexports, went to 43 countries (12 more than in 1999) and consisted of 470,000 t (an 80% increase) valued at $311 million (a 105% increase) for an average of $661 per metric ton (a 14% increase) (U.S. Census Bureau, unpub. data, 2000). The largest tonnages went to the Republic of Korea, 181,000; Taiwan, 80,000; Canada, 47,000; Japan, 46,000; and China, 24,000. These countries received 80% of the total quantity valued at $248 million, which also was 80% of the total value.

U.S. exports of alloy steel scrap (including reexports and excluding stainless steel) were shipped to 46 countries (1 more than in 1999) and consisted of 815,000 t (a 46% increase) valued at $169 million (a 47% increase) for an average of $207 per metric ton (a 1% increase) (U.S. Census Bureau, unpub. data, 2000). The largest tonnages went to China, 295,000; Mexico, 214,000; and Canada, 202,000. These countries received 87% of the total quantity valued at $138 million, which was 82% of the total value.

World Review

Iron and steel scrap is an important raw material for the steel and foundry industries. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars and consumer durables, and manufacturing operations, the relatively mature industrialized economies are generally the main exporters of scrap to lesser developed steelmaking countries.

Germany was the leading exporting country of iron and steel scrap in 1999 (International Iron and Steel Institute, 2000, p. 102), followed by Russia, the United States, Ukraine, Japan, France, the United Kingdom, and Canada. The five most significant importing nations were, in decreasing order of importance, Turkey, the Republic of Korea, Spain, Italy, and the United States (International Iron and Steel Institute, 2000, p. 104).

Outlook

As 2000 opened, the longest economic expansion in U.S. history began its 105th month, and the economies of Asia, Europe, and Latin America were improving. The expectation was for continued strong domestic economic growth and strong demand for steel products and ferrous scrap. In October 2000, the International Iron and Steel Institute forecast an increase in world steel consumption of 5.8% during 2000 and 2.3% during 2001 for a total of 769 Mt in 2001 (International Iron and Steel Institute, [undated], Short and medium term outlook for steel demand, accessed June 5, 2000, at URL http://www.worldsteel.org/ trends_indicators/demand.html). About 15% of the 1999-2000 increase is accounted for by estimates for China. It is predicted that China will soon be consuming more steel than either the European Union (EU) or the countries of the North American Free Trade Agreement. Even without the Chinese contribution to the total, world steel demand is forecast to grow by 35 Mt in 2000 and 7 Mt in 2001, and 43 Mt through 2005. Consumption will increase during 2001 in China, 7.3%; the Commonwealth of Independent States,

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1.2%; the EU, 0.4%; and the Republic of Korea, 4.7%; while the United States and Japan may experience slight declines of less than 1% each. However, by the fourth quarter 2000, the U.S. economy began to soften, as did demand for steel and scrap. Prices for these commodities declined as inventories grew, putting the steel sector back into a depressed state similar to that experienced during the Asian financial crisis 3 years earlier. Imports of low-price steel and scrap again brought calls for relief from unfair dumping. Although the industry was hoping for relief on the imports issue, by yearend 2000 the realization was growing that the problem of excess U.S. uneconomic steelmaking capacity would need a solution.

The United States is the top consumer of ferrous scrap while holding the world's largest stockpile of ferrous scrap resources. The United States has had sufficient scrap resources to satisfy domestic steelmaking needs while being able to export significant scrap quantities to newly emerging economies with developing steelmaking capacities. Steelmaking by the EAF in the minimill will continue to grow in the United States because of its capital and operating cost advantages relative to those of the blast furnace and basic oxygen furance, and it is environmentally cleaner (Darrell Hassler, November 11, 1998, Scrap trade pins hopes on minimills, accessed June 11, 1999, at URL http://www.amm.com/ref/hot/fersc98a.htm#3). In fact, the ratio of EAF steelmaking to BOF steel production has been forecast to increase to 60% from the current 47% (TexReport, 2001).

Continuing expansion of EAF mills in the eastern United States has been absorbing available local scrap resources, thereby causing east coast exports to Europe and Turkey to decline. Demand for scrap in the western United States has not been increasing at a similar pace to that in the eastern United States, and west coast scrap export is expected to increase to satisfy the emerging demand of China, which may displace the Republic of Korea as the largest overseas scrap market.

References Cited

American Iron and Steel Institute, 2000, Annual Report 2000: American Iron and Steel Institute, 130 p.

American Metal Market, 1999, Steel industry bemoans poor rail service and logistics in the East: American Metal Market, v. 107, no. 226, November 23, p. 4.

———2000a, Metal to NRC: Keep radioactive scrap out: American Metal Market, v. 108, January 26, p. 16.

———2000b, Problems for steel coming by train, truck: American Metal Market, v. 108, no. 33, February 18, p. 1.

———2000c, Steel wants better rail service, not mergers: American Metal Market, v. 108, no. 47, March 10, p. 5.

International Iron and Steel Institute, 2000, Steel statistical yearbook 2000: International Iron and Steel Institute, December, 111 p.

Iron and Steelmaker, 2001, 11 countries cited for dumped, subsidized imports: Iron and Steelmaker, v. 28, no. 01, January, p. 14.

Matthews, R.G., 2001, Steelmaker-aid plan draws industry flak as market softens: Wall Street Journal, January 9, p. 1.

New Steel, 1999, Courts rule against EPA in PM2.5 and "overfiling" cases: New Steel, v. 15, no. 13, December, p. 28.

Robertson, Scott, 2000, Norfolk Southern, CSX railroads meeting goals: American Metal Market, v. 108, no. 151, p. 10.

U.S. Environmental Protection Agency, 1998, Atmospheric observations—Helping build the scientific basis for decisions related to airborne particulate matter: U.S. Environmental Protection Agency Report of the PM Measurements Research Workshop, Chapel Hill, NC, July 22-23, 103 p.

Washington Times, 2000a, Court look at clean-air law get green jeers, business cheers: Washington Times, March 31, p. B8.

———2000b, U.S. halts railroad mergers over rules: Washington Times, March 18, p. C11.

Wiener, R.K., 2001, Needed—Automotive design for recycling: New Steel, March 2001, p. 32.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iron and Steel. Ch. in Mineral Commodity Summaries, annual.
Iron and Steel. Ch. in Minerals Yearbook, annual.
Iron and Steel Scrap. Mineral Industry Surveys, monthly.
Iron and Steel Slag. Ch. in Mineral Commodity Summaries, annual.
Iron and Steel Slag. Ch. in Minerals Yearbook, annual.
Iron Ore. Ch. in Mineral Commodity Summaries, annual.
Iron Ore. Ch. in Minerals Yearbook, annual.
Iron Ore. Mineral Industry Surveys, monthly.

Other

American Foundrymen's Society.
American Iron and Steel Institute.
Bureau International de la Recuperation.
Center for Materials Production.
Institute of Scrap Recycling Industries Inc.
Iron and Steel. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Metal Bulletin [London].
Steel Can Recycling Institute.
Steel Manufacturers Association.

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TABLE 1
SALIENT U.S. IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON STATISTICS 1/

(Thousand metric tons, unless otherwise specified)

		1996	1997	1998	1999	2000
Manufacturers of pig iron and raw steel and castings: 2/						
Ferrous scrap consumption		56,000	58,000	58,000	56,000	59,000
Pig iron consumption		50,000	51,000	49,000	48,000	49,000
Direct-reduced iron consumption		1,300	1,300	1,300	2,200	2,300
Net receipts of ferrous scrap 3/		41,000	43,000	44,000	42,000	45,000
Home scrap production 4/		15,000	14,000	14,000	13,000	14,000
Ending stocks of ferrous scrap, December 31		4,800	4,900	4,700	4,800	4,700
Manufacturers of steel castings: 5/						
Ferrous scrap consumption		2,000	1,800	2,000	1,900	2,200
Pig iron consumption		11	13	14	11	11
Net receipts of ferrous scrap 3/		1,300	1,200	1,300	1,200	1,200
Home scrap production 4/		640	660	710	690	980
Ending stocks of ferrous scrap, December 31		84	77	83	230	150
Iron foundries and miscellaneous users: 5/						
Ferrous scrap consumption		13,000	13,000	13,000	13,000	13,000
Pig iron consumption		1,100	1,200	1,200	1,100	1,200
Direct-reduced iron consumption		13	13	12	13	16
Net receipts of ferrous scrap 3/		8,300	8,200	7,900	7,700	7,800
Home scrap production 4/		4,900	5,200	5,100	5,000	4,800
Ending stocks of ferrous scrap, December 31		360	470	440	430	430
Totals, all manufacturing types:						
Ferrous scrap consumption		71,000	73,000	73,000	71,000	74,000
Pig iron consumption		52,000	52,000	50,000	49,000	50,000
Direct-reduced iron consumption		1,300	1,300	1,300	2,200	2,300
Net receipts of ferrous scrap 3/		50,000	52,000	53,000	51,000	54,000
Home scrap production 4/		20,000	20,000	20,000	19,000	20,000
Ending stocks, December 31:						
Ferrous scrap at consumer plants		5,200	5,500	5,200	5,500	5,300
Pig iron at consumer and supplier plants		600	510	560	720	800
Direct-reduced iron at consumer plants		270	160	280	310	290
Exports: 6/						
Ferrous scrap (includes tinplate and terneplate) 7/		8,440	8,930	5,570	5,520	5,760
Value	thousands	$1,340,000	$1,350,000	$805,000	$738,000	$1,000,000
Pig iron (all grades)		58	86	87	83	72
Value	thousands	$8,320	$12,300	$11,700	$11,100	$9,620
Direct-reduced iron (steelmaking grade)		3	8	5	3	2
Value	thousands	$304	$852	$487	$302	$241
Imports for consumption: 6/						
Ferrous scrap (includes tinplate and terneplate) 7/		2,600	2,870	3,060	3,670	3,350
Value	thousands	$342,000	$384,000	$402,000	$383,000	$385,000
Pig iron (all grades)		2,660	3,150	5,150	4,990	4,970
Value	thousands	$411,000	$465,000	$722,000	$527,000	$601,000
Direct-reduced iron (steelmaking grade)		1,050	987	939	950	1,090
Value	thousands	$136,000	$127,000	$118,000	$86,500	$119,000

1/ Data are rounded to no more than two significant digits, except trade data, which are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes manufacturers of raw steel that also produce steel castings.

3/ Net receipts of scrap is defined as receipts from brokers, dealers, and other outside sources, plus receipts from other own-company plants minus shipments.

4/ Home scrap production includes recirculating scrap that results from current operations and obsolete home scrap.

5/ Some consumers in the "Manufacturers of steel castings" category also produce iron castings; some consumers in the "Iron foundries and miscellaneous users" category also produce steel castings.

6/ Data from U.S. Census Bureau. Export valuation is free-alongside-ship (f.a.s.) value, and import valuation is Customs value.

7/ Excludes used rails for rerolling and other uses and ships, boats and other vessels for scrapping.

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TABLE 2
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 2000, BY GRADE 1/

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of purchased and home scrap	Shipments of scrap	Ending stocks, December 31
	From brokers, dealers and other outside sources	From other own-company plants	Recirculating scrap from current operations	Obsolete scrap 2/			
Manufacturers of pig iron and raw steel and castings:							
Carbon steel:							
Low-phosphorus plate and punchings	330	--	(3/)	--	340	13	25
Cut structural and plate	3,800	54	700	51	4,400	66	270
No. 1 heavy melting steel	5,400	330	3,900	24	9,800	79	670
No. 2 heavy melting steel	5,700	76	530	1	6,200	86	490
No. 1 and electric furnace bundles	5,700	310	1,700	(3/)	7,200	490	320
No. 2 and all other bundles	1,000	15	2	(3/)	1,000	--	58
Electric furnace, 1 foot and under (not bundles)	--	9	180	--	86	110	2
Railroad rails	200	2	42	--	230	10	10
Turnings and borings	2,100	72	70	(3/)	2,200	(3/)	130
Slag scrap	790	130	1,300	17	2,100	210	180
Shredded or fragmentized	9,200	970	370	--	11,000	30	570
No. 1 busheling	5,400	130	120	--	5,400	140	350
Steel cans (post consumer)	190	7	40	--	250	--	74
All other carbon steel scrap	2,300	67	2,500	4	4,400	380	390
Stainless steel scrap	820	1	400	--	1,200	1	46
Alloy steel (except stainless)	280	8	560	--	780	25	75
Ingot mold and stool scrap	10	--	120	100	100	130	21
Machinery and cupola cast iron	75	--	5	--	73	1	10
Cast-iron borings	260	--	(3/)	--	250	13	12
Motor blocks	11	--	--	--	11	--	1
Other iron scrap	300	55	460	--	770	150	370
Other mixed scrap	1,000	22	530	(3/)	1,400	89	650
Total	45,000	2,300	14,000	200	59,000	2,000	4,700
Manufacturers of steel castings:							
Carbon steel:							
Low-phosphorus plate and punchings	370	3	83	(3/)	470	(3/)	31
Cut structural and plate	180	--	10	10	190	10	23
No. 1 heavy melting steel	70	--	37	--	110	--	8
No. 2 heavy melting steel	15	--	--	--	12	--	2
No. 1 and electric furnace bundles	11	--	--	--	13	--	(3/)
No. 2 and all other bundles	--	--	--	--	--	--	--
Electric furnace, 1 foot and under (not bundles)	10	5	4	--	18	--	3
Railroad rails	28	--	58	--	86	(3/)	2
Turnings and borings	46	1	6	18	53	18	1
Slag scrap	1	--	3	--	4	--	(3/)
Shredded or fragmentized	120	--	--	--	120	--	2
No. 1 busheling	90	--	6	--	99	--	6
Steel cans (post consumer)	--	--	--	--	--	--	--
All other carbon steel scrap	83	2	230	9	310	15	11
Stainless steel scrap	140	(3/)	300	28	450	29	36
Alloy steel (except stainless)	72	1	50	(3/)	120	(3/)	8
Ingot mold and stool scrap	10	--	43	--	33	19	6
Machinery and cupola cast iron	--	--	--	--	--	--	(3/)
Cast-iron borings	--	--	1	--	1	--	(3/)
Motor blocks	1	--	--	--	1	--	(3/)
Other iron scrap	9	--	60	--	69	1	2
Other mixed scrap	52	--	1	14	65	1	5
Total	1,300	11	900	79	2,200	92	150

See footnotes at end of table.

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TABLE 2--Continued
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 2000, BY GRADE 1/

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of purchased and home scrap	Shipments of scrap	Ending stocks, December 31
	From brokers, dealers and other outside sources	From other own-company plants	Recirculating scrap from current operations	Obsolete scrap 2/			
Iron foundries and miscellaneous users:							
Carbon steel:							
Low-phosphorus plate and punchings	950	5	160	(3/)	1,100	(3/)	18
Cut structural and plate	1,300	32	110	(3/)	1,500	(3/)	120
No. 1 heavy melting steel	220	3	16	(3/)	230	2	9
No. 2 heavy melting steel	150	1	--	--	160	--	3
No. 1 and electric furnace bundles	93	140	32	--	260	--	12
No. 2 and all other bundles	88	--	1	--	88	1	2
Electric furnace, 1 foot and under (not bundles)	140	--	1	--	140	1	3
Railroad rails	140	--	9	--	150	--	6
Turnings and borings	87	65	3	--	160	4	3
Slag scrap	42	--	3	--	40	3	4
Shredded or fragmentized	1,500	110	(3/)	--	1,700	--	55
No. 1 busheling	670	62	56	--	780	39	17
Steel cans (post consumer)	14	--	--	--	14	--	(3/)
All other carbon steel scrap	120	(3/)	42	--	170	(3/)	12
Stainless steel scrap	6	--	4	--	9	(3/)	6
Alloy steel (except stainless)	13	--	1	--	14	--	2
Ingot mold and stool scrap	61	--	2	(3/)	63	--	10
Machinery and cupola cast iron	740	--	310	(3/)	1,100	1	56
Cast-iron borings	190	89	47	1	320	8	5
Motor blocks	240	10	740	--	1,000	2	9
Other iron scrap	240	3	3,100	--	3,300	9	67
Other mixed scrap	210	23	150	(3/)	380	(3/)	14
Total	7,300	540	4,800	2	13,000	71	430
Totals for all manufacturing types:							
Carbon steel:							
Low-phosphorus plate and punchings	1,600	8	240	(3/)	1,900	14	75
Cut structural and plate	5,400	86	810	61	6,100	76	420
No. 1 heavy melting steel	5,700	340	4,000	24	10,000	81	680
No. 2 heavy melting steel	5,800	77	530	1	6,400	86	490
No. 1 and electric furnace bundles	5,800	440	1,700	(3/)	7,500	490	330
No. 2 and all other bundles	1,100	15	3	(3/)	1,100	1	60
Electric furnace, 1 foot and under (not bundles)	150	14	180	--	250	110	7
Railroad rails	370	2	110	--	470	10	19
Turnings and borings	2,200	140	79	18	2,400	22	130
Slag scrap	830	130	1,300	17	2,200	210	180
Shredded or fragmentized	11,000	1,100	370	--	12,000	30	630
No. 1 busheling	6,200	200	190	--	6,300	180	370
Steel cans (post consumer)	200	7	40	--	260	--	74
All other carbon steel scrap	2,500	69	2,800	13	4,900	390	410
Stainless steel scrap	960	1	700	28	1,700	30	88
Alloy steel (except stainless)	360	8	610	(3/)	920	25	85
Ingot mold and stool scrap	81	--	170	100	200	150	37
Machinery and cupola cast iron	810	--	320	(3/)	1,100	3	66
Cast-iron borings	450	89	47	1	570	22	17
Motor blocks	260	10	740	--	1,000	2	10
Other iron scrap	550	58	3,600	--	4,200	160	440
Other mixed scrap	1,300	45	680	14	1,900	90	670
Total	53,000	2,800	19,000	280	74,000	2,200	5,300

-- Zero.

1/ Data are rounded to no more than two significant digits; may not add to totals shown.

2/ Obsolete home scrap includes ingot molds, stools, and scrap from old equipment, buildings, etc.

3/ Less than 1/2 unit.

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TABLE 3
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF PIG IRON AND DIRECT-REDUCED IRON (DRI) IN 2000 1/

(Thousand metric tons)

	Receipts	Production	Consumption	Shipments	Stocks, December 31
Manufacturers of pig iron, raw steel, castings:					
Pig iron	10,000 2/	42,000	49,000	1,900	660
DRI	2,200 3/	W	2,300	17	290
Manufacturers of steel castings:					
Pig iron	11	(4/)	11	(5/)	1
DRI	--	--	--	--	--
Iron foundries and miscellaneous users:					
Pig iron	1,200	(4/)	1,200	41	130
DRI	16	1	16	--	(5/)
Totals for all manufacturing types:					
Pig iron	11,000	42,000	50,000	1,900	800
DRI	2,200	W	2,300	17	290

W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than two significant digits; may not add to totals shown.
2/ Includes 1,600 tons purchased by electric furnace steel producers.
3/ Includes 1,300 tons purchased by integrated steel producers.
4/ Withheld to avoid disclosing company proprietary data; included in "Total."
5/ Less than 1/2 unit.

TABLE 4
U.S. CONSUMPTION OF IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON (DRI) IN 2000, BY TYPE OF FURNACE OR OTHER USE 1/

(Thousand metric tons)

	Manufacturers of pig iron, raw steel, castings			Manufacturers of steel castings			Iron foundries and miscellaneous users			Totals for all manufacturing types		
	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI
Blast furnace	1,500	--	330	--	--	--	--	--	--	1,500	--	330
Basic oxygen process	15,000	47,000	100	--	--	--	--	--	--	15,000	47,000	100
Electric furnace	43,000	2,200	1,800	2,100	11	--	5,300	700	5	50,000	2,900	1,800
Cupola furnace	--	--	--	100	1	--	7,300	520	11	7,400	530	11
Other (including air furnaces)	W	--	--	2	--	--	W	W	--	2	W	--
Direct castings 2/	--	35	--	--	--	--	--	--	--	--	35	--
Total	59,000	49,000	2,300	2,200	11	--	13,000	1,200	16	74,000	50,000	2,300

W Withheld to avoid disclosing company proprietary data; included with "Electric furnace." -- Zero.
1/ Data are rounded to no more than two significant digits; may not add to totals shown.
2/ Includes ingot molds and stools.

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TABLE 5
IRON AND STEEL SCRAP SUPPLY AVAILABLE FOR CONSUMPTION IN 2000, BY REGION AND STATE 1/ 2/

(Thousand metric tons)

Region and State	Receipts of scrap: From brokers, dealers, other outside sources	Receipts of scrap: From other own company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap 3/	Shipments of scrap 4/	New supply available for consumption
New England and Middle Atlantic:						
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	47	--	30	1	(5/)	76
New Jersey and New York	1,800	--	110	7	1	1,900
Pennsylvania	4,200	98	2,400	77	18	6,800
Total	6,100	98	2,600	85	20	8,800
North Central:						
Illinois	3,400	86	1,000	2	170	4,300
Indiana	4,200	190	5,100	39	620	8,900
Iowa, Nebraska, South Dakota	1,900	3	210	--	(5/)	2,200
Kansas and Missouri	830	3	250	65	83	1,100
Michigan	3,200	440	1,900	(5/)	200	5,300
Minnesota	450	170	110	--	(6/)	730
Ohio	7,400	800	2,300	43	780	9,800
Wisconsin	1,200	3	1,000	(5/)	6	2,200
Total	23,000	1,700	12,000	150	1,900	34,000
South Atlantic:						
Delaware and Maryland	680	1	430	--	(6/)	1,100
Florida and Georgia	950	--	160	--	(5/)	1,100
North Carolina and South Carolina	2,100	(6/)	230	--	(6/)	2,300
Virginia and West Virginia	1,800	(6/)	600	(6/)	(6/)	2,500
Total	5,500	160	1,400	(6/)	160	7,000
South Central:						
Alabama and Mississippi	3,700	(6/)	1,000	(6/)	83	4,700
Arkansas, Louisiana, Oklahoma	4,300	(6/)	380	(6/)	(6/)	4,700
Kentucky and Tennessee	3,200	2	510	--	(6/)	3,600
Texas	3,300	760	610	10	4	4,700
Total	14,000	860	2,500	24	140	18,000
Mountain and Pacific:						
Arizona, Colorado, Idaho, Montana, Utah	2,200	(5/)	550	(6/)	(6/)	2,800
California, Oregon, Washington	2,600	W	310	(5/)	(6/)	2,900
Total	4,800	W	850	(6/)	5	5,700
Grand total	53,000	2,800	19,000	280	2,200	74,000

W Withheld to avoid disclosing company proprietary data. -- Zero.

1/ Supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The difference in stock levels at the beginning and end of the year is not taken into consideration.

2/ Data are rounded to no more than two significant digits; may not add to totals shown.

3/ Obsolete scrap includes ingot molds, stools and scrap from old equipment, buildings, etc.

4/ Includes scrap shipped, transferred, or otherwise disposed of during the year.

5/ Less than 1/2 unit.

6/ Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total."

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TABLE 6
U.S. CONSUMPTION OF IRON AND STEEL SCRAP AND PIG IRON IN 2000, BY REGION AND STATE 1/ 2/ 3/

(Thousand metric tons)

Region and State	Manufacturers of pig iron, raw steel, castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Totals for all manufacturing types	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,600	24	20	(4/)	390	17	2,000	41
Pennsylvania	6,300	3,000	180	2	580	79	7,100	3,100
Total	7,900	3,000	200	2	980	96	9,100	3,100
North Central:								
Illinois	3,800	2,700	140	2	570	36	4,500	2,800
Indiana	8,000	17,000	69	1	1,100	150	9,200	17,000
Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota, Wisconsin	3,000	110	480	3	2,400	320	5,900	430
Michigan	2,700	5,000	31	(4/)	2,500	170	5,200	5,200
Ohio	7,800	9,800	430	2	1,300	130	9,500	9,900
Total	25,000	34,000	1,200	8	7,800	810	34,000	35,000
South Atlantic:								
Delaware, Maryland, Virginia, West Virginia	2,900	W	W	W	470	21	3,400	4,400
Florida, Georgia, North Carolina, South Carolina	2,900	W	W	W	480	37	3,400	75
Total	5,900	4,400	4	W	960	58	6,800	4,500
South Central:								
Alabama, Kentucky, Mississippi, Tennessee	5,800	W	620	W	1,900	W	8,300	5,000
Arkansas, Louisiana, Oklahoma	4,700	W	25	W	120	W	4,800	600
Texas	4,200	62	89	W	420	38	4,700	100
Total	15,000	5,500	730	W	2,400	200	18,000	5,700
Mountain and Pacific:								
Arizona, Colorado, Idaho, Montana, Utah	2,700	W	22	(4/)	130	W	2,900	1,900
California, Oregon, Washington	2,400	W	120	(4/)	320	W	2,900	110
Total	5,200	1,900	140	(4/)	460	58	5,800	2,000
Grand total	59,000	49,000	2,200	11	13,000	1,200	74,000	50,000

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total."

1/ Includes recirculating scrap resulting from current operations and home-generated obsolete scrap.

2/ Includes molten pig iron used for ingot molds and direct castings.

3/ Data are rounded to no more than two significant digits; may not add to totals shown.

4/ Less than 1/2 unit.

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TABLE 7
U.S. CONSUMER STOCKS OF IRON AND STEEL SCRAP AND PIG IRON, DECEMBER 31, 2000, BY REGION AND STATE 1/

(Thousand metric tons)

Region and State	Carbon steel 2/	Stainless steel	Alloy steel 3/	Cast iron 4/	Other grades of scrap	Total scrap	Pig iron
New England and Middle Atlantic:							
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	(5/)	1	(5/)	1	W	1	1
New Jersey and New York	71	1	1	1	W	76	1
Pennsylvania	340	33	20	28	5	420	29
Total	410	35	21	30	5	500	31
North Central:							
Illinois	320	(5/)	W	18	3	340	35
Indiana	500	5	W	120	13	640	210
Iowa, Kansas, Missouri, Nebraska, South Dakota	170	(5/)	1	14	W	180	99
Michigan	130	6	1	18	45	200	70
Minnesota and Wisconsin	41	2	1	9	2	54	9
Ohio	440	27	45	33	4	550	33
Total	1,600	40	49	210	68	2,000	460
South Atlantic:							
Delaware, Maryland, Virginia, West Virginia	270	(5/)	W	17	46	330	57
Florida, Georgia, North Carolina, South Carolina	120	(5/)	W	23	3	150	7
Total	390	(5/)	3	40	49	480	64
South Central:							
Alabama, Kentucky, Mississippi, Tennessee	650	W	W	260	W	1,400	140
Arkansas, Louisiana, Oklahoma	360	W	W	4	W	370	68
Texas	250	W	W	4	W	260	21
Total	1,300	12	6	270	500	2,000	220
Mountain and Pacific:							
Arizona, Colorado, Idaho, Montana, Utah	140	(5/)	W	6	--	150	W
California, Oregon, Washington	93	(5/)	W	16	53	170	W
Total	230	1	5	22	53	310	17
Grand total	3,900	88	84	570	670	5,300	800

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total." -- Zero.
1/ Data are rounded to no more than two significant digits; may not add to totals shown.
2/ Excludes rerolling rails.
3/ Excludes stainless steel.
4/ Includes borings.
5/ Less than 1/2 unit.

TABLE 8
U.S. AVERAGE MONTHLY PRICE AND COMPOSITE PRICE FOR NO. 1 HEAVY MELTING STEEL, WITH ANNUAL AVERAGES 1/

(Dollars per metric ton)

Period	Chicago	Philadelphia	Pittsburgh	Composite price
2000:				
January	118.60	115.10	126.47	120.06
February	109.35	101.52	117.12	109.33
March	108.75	101.37	116.63	108.92
April	106.44	103.83	116.23	108.84
May	99.90	97.44	108.75	102.03
June	93.10	92.52	102.85	96.15
July	91.04	87.59	97.93	92.19
August	91.04	82.80	97.93	90.59
September	91.04	82.67	97.93	90.55
October	81.29	74.31	88.18	81.26
November	71.65	71.85	76.57	73.36
December	73.03	80.26	78.79	77.36
Annual average:				
2000	94.60	90.94	102.11	95.88
1999	100.91	85.16	96.37	94.15

1/ Calculated by the U.S. Geological Survey from prices published in American Metal Market.

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TABLE 9
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY COUNTRY 1/ 2/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value	Quantity	Value
Australia	(3/)	355	1	469
Belgium	3	1,770	16	11,200
Brazil	3	505	2	1,680
Canada	1,700	182,000	1,280	159,000
China	419	96,200	1,080	216,000
Colombia	30	3,380	5	690
France	15	2,450	1	322
Germany	9	2,610	5	2,090
Hong Kong	48	13,600	45	13,800
India	17	5,770	61	18,100
Indonesia	6	1,590	10	2,590
Israel	1	1,130	3	1,230
Italy	5	2,080	7	3,350
Japan	72	15,400	73	47,100
Korea, Republic of	1,870	215,000	1,440	142,000
Malaysia	46	4,360	95	9,450
Mexico	849	88,100	1,010	109,000
Netherlands	3	1,730	16	11,100
Philippines	17	8,290	18	10,500
Saudi Arabia	(3/)	27	33	2,960
Singapore	2	803	3	2,300
South Africa	16	10,100	13	9,110
Spain	32	16,700	81	118,000
Sweden	1	672	5	148
Taiwan	220	44,100	297	82,600
Thailand	58	6,930	134	16,000
United Kingdom	13	4,760	8	3,220
Other	64 r/	8,760 r/	23	8,090
Total	5,520	738,000	5,760	1,000,000

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Export valuation is free-alongside-ship (f.a.s.) value. The United States exported scrap to 70 countries in 1999 and 88 countries in 2000.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY CUSTOMS DISTRICT 1/ 2/

(Thousand metric tons and thousand dollars)

Customs district	1999		2000	
	Quantity	Value	Quantity	Value
Boston, MA	328	30,500	336	32,500
Buffalo, NY	148	27,300	129	30,800
Columbia-Snake	52	10,300	105	22,700
Detroit, MI	411	46,900	220	35,000
Honolulu, HI	45	5,250	96	12,800
Houston-Galveston, TX	66	28,500	73	49,200
Laredo, TX	193	21,800	361	41,100
Los Angeles, CA	1,120	155,000	1,230	231,000
Mobile, AL	40	22,300	39	26,400
New Orleans, LA	50	13,900	47	34,700
New York, NY	379	64,200	357	109,000
Nogales, AZ	9	948	47	5,580
Norfolk, VA	118	15,700	84	20,700
Pembina, ND	361	32,600	272	26,900
Portland, ME	79	8,010	69	7,640
Providence, RI	140	10,700	240	24,500
San Francisco, CA	706	90,600	847	125,000
San Juan, PR	11	5,430	69	4,830
Seattle, WA	277	40,300	303	53,100
St Albans, VT	38	7,860	66	12,200
Tampa, FL	2	415	64	6,990
Other	947 r/	100,000 r/	711	88,000
Total	5,520	738,000	5,760	1,000,000

r/ Revised.
1/ Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Export valuation is free-alongside-ship (f.a.s.) value.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 11
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY GRADE 1/ 2/

(Thousand metric tons and thousand dollars)

Grade	1999		2000	
	Quantity	Value	Quantity	Value
No. 1 heavy melting scrap	931	77,200	778	77,200
No. 2 heavy melting scrap	245	19,300	181	17,400
No. 1 bundles	42	3,800	52	5,120
No. 2 bundles	32	2,180	31	2,800
Shredded steel scrap	1,190	112,000	1,350	140,000
Borings, shovelings and turnings	230	15,600	214	15,700
Cut plate and structural	284	29,000	156	17,200
Tinned iron or steel	90	21,500	123	28,600
Remelting scrap ingots	2	664	3	1,600
Stainless steel scrap	260	151,000	468	310,000
Other alloy steel scrap	558	115,000	809	168,000
Other steel scrap 3/	940	101,000	939	132,000
Iron scrap	715	89,300	658	85,000
Total	5,520	738,000	5,760	1,000,000
Ships, boats, other vessels for scrapping	7	2,610	11	153
Used rails for rerolling and other uses 4/	34	14,300	40	15,600
Grand total	5,560	755,000	5,810	1,020,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Export valuation is on a free-alongside-ship (f.a.s.) value.
3/ Includes tinplate and terneplate.
4/ Includes mixed (used plus new) rails. See table 15 for details.

Source: U.S. Census Bureau.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY COUNTRY 1/ 2/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value	Quantity	Value
Australia	19	1,900	(3/)	216
Belgium	30	3,270	53	10,200
Brazil	12	609	3	2,850
Canada	1,830	181,000	1,870	196,000
China	3	1,870	(3/)	54
Dominican Republic	32	3,090	32	3,630
Egypt	2	1,970	2	1,480
Finland	106	9,170	32	3,500
France	(3/)	73	1	173
Germany	(3/)	360	31	4,010
Jamaica	7	638	6	686
Japan	26	3,740	140	8,920
Mexico	62	26,600	63	29,200
Netherlands	218	21,000	129	13,800
Netherlands Antilles	4	355	4	440
Norway	--	--	15	1,420
Panama	2	107	1	168
Russia	98	6,840	91	8,920
Singapore	2	24	8	2,800
South Africa	6	2,000	(3/)	2
Sweden	175	16,100	200	21,000
Trinidad and Tobago	(3/)	45	(3/)	210
Ukraine	(3/)	14	(3/)	13
United Kingdom	976	95,600	652	71,300
Venezuela	4	523	8	1,920
Other	58 r/	5,780 r/	12	2,260
Total	3,670	383,000	3,350	385,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Import valuation is Customs value. The United States imported scrap from 52 countries in 2000 and 53 countries in 1999.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP,
BY CUSTOMS DISTRICT 1/ 2/

(Thousand metric tons and thousand dollars)

Customs district	1999		2000	
	Quantity	Value	Quantity	Value
Buffalo, NY	187	28,800	151	23,900
Charleston, SC	75	6,990	245	25,600
Chicago, IL	145	11,200	79	5,170
Cleveland, OH	28	1,790	38	3,580
Detroit, MI	1,110	107,000	1,110	113,000
El Paso, TX	6	2,020	7	2,090
Laredo, TX	44	17,500	59	24,300
Los Angeles, CA	6	327	59	798
Mobile, AL	52	5,210	21	2,670
New Orleans, LA	1,670	159,000	1,150	128,000
Ogdensburg, NY	19	3,710	31	5,110
Pembina, ND	25	7,610	21	5,970
Philadelphia, PA	(3/)	59	27	3,610
San Diego, CA	12	5,530	8	5,220
Seattle, WA	264	20,400	338	26,700
Other	32	6,800	18	8,420
Total	3,670	383,000	3,350	385,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Import valuation is Customs value.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CLASS 1/ 2/

(Thousand metric tons and thousand dollars)

Class	1999		2000	
	Quantity	Value	Quantity	Value
No. 1 heavy melting scrap	46	3,660	23	2,020
No. 2 heavy melting scrap	16	1,480	5	417
No. 1 bundles	246	23,100	248	25,000
No. 2 bundles	1	74	35	4,140
Shredded steel scrap	1,080	103,000	885	92,100
Borings, shovelings and turnings	138	10,800	76	5,640
Cut plate and structural	134	13,200	113	13,300
Tinned iron or steel	58	5,270	15	1,660
Remelting scrap ingots	5	1,860	34	5,590
Stainless steel scrap	66	27,700	56	35,500
Other alloy steel scrap	210	29,700	377	44,900
Other steel scrap 3/	1,320	135,000	1,020	119,000
Iron scrap	354	28,300	466	35,300
Total	3,670	383,000	3,350	385,000
Ships, boats, other vessels for scrapping	(4/)	189	--	--
Used rails for rerolling and other uses 5/	348	43,900	271	34,100
Grand total	4,020	427,000	3,630	419,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Import valuation is Customs value.
3/ Includes tinplate and terneplate.
4/ Less than 1/2 unit.
5/ Includes mixed (used plus new) rails. See table 16 for details.

Source: U.S. Census Bureau.

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TABLE 15
U.S. EXPORTS OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY 1/ 2/

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Bahamas, The	21	$90	405	$360
Canada	9,290	2,090	12,800	2,740
Chile	63	64	2,310	1,140
Dominican Republic	566	232	207	191
Mexico	21,800	8,850	23,000	9,540
Netherlands	--	--	289	142
United Kingdom	516	296	204	137
Venezuela	70	87	412	319
Other	1,430 r/	2,590 r/	745	1,080
Total	33,700 r/	14,300 r/	40,400	15,600

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Exports contain mixed (used plus new) rails totaling 7,590 metric tons valued at $8,580,000 in 2000 and 7,700 metric tons valued at $7,390,000 in 1999. Export valuation is free-alongside-ship (f.a.s.) value.

Source: U.S. Census Bureau.

TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY 1/ 2/

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Canada	28,700	5,490	21,100	4,120
France	1	2	49	26
New Zealand	--	--	5	5
Poland	41,400	8,370	10,300	1,500
Romania	--	--	9,570	951
Russia	255,000 r/	27,600	217,000	25,600
Ukraine	13,600	1,410	13,200	1,660
Other	9,360 r/	964 r/	327	300
Total	348,000 r/	43,900	271,000	34,100

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Import valuation is Customs value.

Source: U.S. Census Bureau.

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TABLE 17
U.S. EXPORTS OF DIRECT-REDUCED IRON (DRI), BY COUNTRY 1/ 2/

Country	1999 r/ Quantity (metric tons)	1999 r/ Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Australia	--	--	53	$6
Canada	--	--	86	9
Italy	--	--	28	3
Japan	--	--	26	3
Mexico	653	$69	1,440	181
Taiwan	40	4	137	14
United Kingdom	26	3	62	11
Other	2,560	226	139	15
Total	3,270	302	1,970	241

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Data are for steelmaking-grade DRI only.

Source: U.S. Census Bureau.

TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF DIRECT-REDUCED IRON (DRI), BY COUNTRY 1/ 2/

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Argentina	35,300	$3,510	--	--
Canada	23	3	12,400	$2,180
Japan	19,000	2,010	--	--
Mexico	--	--	--	--
Norway	--	--	450	48
Trinidad and Tobago	26,300	2,110	64,000	6,560
Venezuela	870,000	78800	1,010,000	110000
Total	950,000	86,500	1,090,000	119,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Data are for steelmaking-grade DRI only.

Source: U.S. Census Bureau.

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TABLE 19
U.S. EXPORTS OF PIG IRON, BY COUNTRY 1/ 2/

Country	1999 Quantity metric tons)	1999 Value (thousands)	2000 Quantity metric tons)	2000 Value (thousands)
Australia	2,430	$214	1,400	$123
Canada	10,100	1,680	4,270	761
China	--	--	186	39
Korea, Republic of	--	--	839	74
Malaysia	--	--	1,140	100
Mexico	64,300	8,500	58,700	8,020
Saudi Arabia	--	--	540	47
Singapore	224	20	355	31
South Africa	--	--	1,730	152
Spain	--	--	1,260	111
Taiwan	397	35	338	30
United Kingdom	--	--	432	38
Other	5,550 r/	610 r/	932	99
Total	83,000	11,100	72,100	9,620

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes the following grades of pig iron: less than or equal to 0.5% phosphorus content, greater than 0.5% phosphorus content, and alloy grade. Export valuation is free-alongside-ship (f.a.s.) value.

Source: U.S. Census Bureau.

TABLE 20
U.S. IMPORTS FOR CONSUMPTION OF PIG IRON, BY COUNTRY 1/ 2/

Country	1999 Quantity metric tons)	1999 Value (thousands)	2000 Quantity metric tons)	2000 Value (thousands)
Brazil	2,540,000	$271,000	3,080,000	$374,000
Canada	117,000	20,700	109,000	18,300
China	20,700	2,340	41,100	4,740
Japan	112,000	11,000	5	10
Norway	5,190	552	5,000	617
Poland	--	--	12,400	1,640
Russia	688,000	63,100	423,000	45,200
South Africa	221,000	29,100	145,000	18,100
Switzerland	354,000	33,400	16,000	2,210
Turkey	--	--	44,000	5,520
Ukraine	921,000	94,600	1,070,000	129,000
Venezuela	--	--	23,000	2,370
Other	15,000 r/	1,410 r/	27	7
Total	4,990,000	527,000	4,970,000	601,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes the following grades of pig iron: less than or equal to 0.5% phosphorus content, greater than 0.5% phosphorus content, and alloy grade. Import valuation is Customs value.

Source: U.S. Census Bureau.

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IRON ORE

By William S. Kirk

Domestic survey data and tables were prepared by Heather A. Geissler, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Domestic production of iron ore in 2000 increased by 9%, reflecting an increase in steel production with the attendant increase in pig iron production. Similarly, world iron ore output rose reflecting higher levels of steel and pig iron production. There were major acquisitions in the iron ore industry. Iron ore prices increased.

Iron ore is essential to the economy and national security of the United States. As the basic raw material from which iron and steel are made, its supply is critical to any industrial country. Scrap is used as a supplement in steelmaking but is limited as a major feed material because the supply of high-quality scrap is limited. However, alternatives, such as direct reduced iron (DRI), were available, and their use is growing. In 2000, the steel industry accounted for more than 98.5% of iron ore consumption.

Iron ore is a mineral substance which, when heated in the presence of a reductant, will yield metallic iron. It almost always consists of iron oxides, the primary forms of which are magnetite (Fe_3O_4) and hematite (Fe_2O_3). Taconite, the principal iron ore mined in the United States, has a low (20% to 30%) Fe content and is found in hard, fine-grained, banded iron formations.

Production

Following a year marked by reduced demand for iron ore, U.S. iron ore production in 2000 reached its highest level since 1981, 63.0 million metric tons (Mt).

The nine taconite mining operations in Michigan and Minnesota accounted for virtually all domestic iron ore production. Seven of these operations were on the Mesabi Iron Range in northeastern Minnesota: EVTAC Mining LLC, Hibbing Taconite Co., Inland Steel Mining Co., LTV Steel Mining Co., National Steel Pellet Co., Northshore Mining Co., and the US Steel Group of USX Corp. (Minntac). The two taconite operations on the Marquette Iron Range in the Upper Peninsula of Michigan were the Empire and the Tilden Mines.

U.S. production data for iron ore are developed by the U.S. Geological Survey (USGS) by means of the annual "Iron Ore" survey, which provided 100% of total production shown in tables 1 through 4. This information is supplemented by employment data, mine inspection reports, and information from consumers. The American Iron Ore Association (AIOA) provided data on ore shipments from loading docks on the upper Great Lakes, as well as receipts at transfer docks and furnace yards nationwide. The dock and steel plant data were compiled jointly by AIOA and the American Iron and Steel Institute (AISI).

Iron ore was produced by 13 companies. One other company did not produce ore, but shipped it from stockpiles. The nine taconite producers in Michigan and Minnesota accounted for 99% of domestic production. The producing companies operated 13 mining operations, 10 iron ore concentration plants, and 10 pelletizing plants. Of the two iron ore producers that did not produce pellets, one produced iron ore as a byproduct of gold mining, and the others produced direct-shipping ore, which requires minimal processing. Of the 13 mining operations, 12 were open pit and 1 was underground. Virtually all ore was concentrated before shipment, and 99% was pelletized. In 2000, combined United States and Canadian production represented 9% of the world output of usable ore in terms of metal content. Trends in world mine production since 1996 are shown on a country basis in table 17.

Domestic iron ore supply (production minus exports) satisfied 75% of domestic demand in 2000, compared with an average of 70% from 1990 through 2000. Domestic iron ore production, at 63 Mt, increased by 9% from that of 1999. Productivity in the Lake Superior District, in terms of thousands of tons of usable

Iron Ore in the 20th Century

From well before 1900 and into 2000 virtually all iron ore has been used to make steel, so the iron ore industry's fortunes were and continued to be inextricably linked to those of the steel industry. In 1904, the United States was the world's largest iron ore producer, accounting for about 60% of total world output of 46 million metric tons (Mt). Despite this, the United States was already a net importer of iron ore, if only by a small margin. After domestic production peaked at 127 Mt during World War II, it became apparent that U.S. reserves of high-grade ore would be seriously depleted by the 1950s. It was in this decade that production of high-grade pelletized concentrate began. Despite the need for much more processing, compared with the direct shipping ores of the past, the use of pellets made blast furnaces much more productive.

By the end of the 20th century, world iron ore production had grown to more than 1 billion tons per year. In the United States, however, production averaged about 60 million tons per year (Mt/yr) and consumption averaged 77 Mt/yr. The United States ranked as the sixth largest producing nation and accounted for only 6% of world production. Globally, the proportion of ore production that was exported continued to grow, reaching almost 45%. Australia and Brazil increasingly dominated that export market, capturing almost 70%. The end of the 20th century saw a wave of consolidation in the iron ore industry as producers strove to reduce production costs and become more competitive.

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ore produced per worker in 2000, was 9.3, an 8% increase from that of 1999. Low-grade ores of the taconite type mined in Michigan and Minnesota accounted for 99% of total usable ore production. U.S. production of pellets totaled 62.4 Mt. The average Fe content of usable ore produced was 62.9%. Fluxed pellets' share of total pellet production was 60% in 2000.

Michigan.—Michigan accounted for 23.8% of the output of usable ore in 2000. Pellets accounted for 99% of total production.

Minnesota.—Minnesota produced 76.1% of the national output of usable ore in 2000. All the State's production came from open pit mines on the Mesabi Range.

LTV Steel Co., Inc., a subsidiary of The LTV Corp., on May 24, announced its intention to close permanently the operations of LTV Steel Mining Co. (LTVSMC). LTVSMC was located at Hoyt Lakes, MN, employed approximately 1,400 people, and produced about 7 Mt of pellets in 1999. LTV Steel stated that its blast furnaces were experiencing lower levels of productivity and higher costs as a result of operating problems related to poor taconite pellet quality. The poor quality pellet was the result of deteriorating ore quality and the obsolete shaft furnaces used in the pelletizing plant. LTVSMC operated the only remaining shaft furnaces in the North American taconite pellet industry. These maintenance-intensive furnaces were not competitive with modern straight grate or grate kiln furnaces, which produce better quality pellets at lower cost. Replacement of the shaft furnaces and other related changes would require investments of about $500 million within 3 years, and a total investment of about $700 million in the next 10 years. The company said that such an investment could not be justified and would not resolve the problems of poor quality ore reserves (Kirk, 2000a).

Another major problem at the mine was the high stripping ratio. Stripping is the removal of layers of soil and waste rock that cover the ore. The more overburden that must be stripped to expose the crude ore, the higher the stripping ratio and, consequently, the higher the production costs. The iron formation on the Mesabi Range dips at an angle of about 8 degrees. Mining must follow the iron formation down dip, and as it proceeds, the overburden becomes thicker. Because LTVSMC was the oldest continuously operating taconite mining operation on the Minnesota Iron Range, and had some of the deepest pits, it had considerably more stripping to do than the other producers (Kirk, 2000a).

Minntac closed one of its agglomerating lines on November 5th for the remainder of the year. National Steel Pellet Co. announced that it would lay off 22 employees at the end of the year. The closings were attributed to low iron ore demand that was the result of high levels of steel imports (Lee Bloomquist, Duluth News Tribune, November 7, 2000, Minntac layoffs delayed—Agreement prevents cuts until year's end, accessed November 7, 2000, at URL http://www.duluthnews.com/today/dnt/tac.htm; Lee Bloomquist, Duluth News Tribune, December 8, 2000, Keewatin taconite plant to lay off 22, accessed December 8, 2000, at URL http://www.duluthnews.com/today/dnt/nat.htm).

Missouri.—Pea Ridge Iron Ore Co. produced iron oxide powder at its mining complex near Sullivan. The company has the only active underground iron ore mine in the country. In January 1991, the company ceased pellet production and began concentrating on specialty iron oxide products, which had formerly been coproducts.

Consumption

Data on consumption and stocks of iron ore and iron ore agglomerates (pellets and sinter) at iron and steel plants were provided by the AIOA. Data on consumption of iron ore for nonsteel end uses were compiled from information gathered from USGS surveys. Domestic iron ore consumption, responding to increased steel production, rose 2%, to 76 Mt. Stocks and net imports increased.

The number of blast furnaces in operation during the year ranged from 33 to 36. Consumption of iron ore, including agglomerates reported to the AISI by integrated producers of iron and steel, totaled 73 Mt. This included 61.8 Mt of pellets; 10.8 Mt of sinter, briquettes, etc.; and 0.4 Mt of natural coarse ore. Of the ore consumed, 82% was of domestic origin, 9% came from Canada, and 9% came from other countries. Other materials consumed in sintering plants included mill scale, flue dust, limestone and dolomite, slag and slag scrap, and coke breeze. Other iron-bearing materials charged to blast furnaces included mill scale, slag scrap, and steel-furnace slag.

The four consumption numbers in this annual review are listed in tables 1, 6, 7, and 8. The following explains why more than one consumption number is used and how each of them is derived. The first consumption number (76.5 Mt in 2000) is in table 1 and is the sum of the quantity of ore consumed by form as reported by the AISI (American Iron and Steel Institute, 2000, p. 84) and the quantities of ore consumed in DRI production and ore consumed in nonsteel uses, as reported to the USGS; the AISI number is reported in short tons and is converted to metric tons. The second consumption number (70.7 Mt in 2000) is in table 6 and is the quantity of ore consumed at U.S. iron and steel plants by originating area, as reported by the AIOA; the number has been converted from long tons, as it appears in the AIOA annual report, to metric tons (American Iron Ore Association, 2000, p. 42). The third consumption number (73.0 Mt in 2000) is in table 7 and is the quantity of ore consumed in U.S. iron and steel plants by type of ore as reported by the AISI; the number has been converted from short tons, as it is listed in the AISI annual report, to metric tons (American Iron and Steel Institute, 2000, table 32). The fourth consumption number (74.1 Mt in 2000) is in table 8 and is the sum of the AIOA number for consumption at United States Iron and Steel plants (American Iron Ore Association, 2000, p. 46, 47) and two other numbers; these are the quantities of ore consumed in DRI production (2.3 Mt in 2000) and nonsteel uses (1.2 Mt in 2000) as reported to the USGS. In summary, iron ore consumption for steelmaking is calculated by the AIOA and the AISI using different methods. To obtain total domestic iron ore consumption, iron ore consumption for other end uses must be added to AIOA and AISI reported consumption, thereby generating four consumption numbers.

Ispat International NV planned to install electric arc furnaces at its Inland Works in East Chicago to replace the No. 2 oxygen steelmaking shop there. Blast furnaces nos. 5 and 6 were nearing the end of their working lives, but were not to be replaced. Instead, Ispat planned to put in two electric furnaces with a combined capacity of about 3 million metric tons per year (Mt/yr), about the same as the existing facilities (Metal Bulletin, 2000q).

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Prices

Most iron ore prices are negotiated between buyer and seller. In 2000, 79% of domestic ore was produced by captive mines (mines producing for company-owned blast furnaces) and, therefore, did not reach the open market and cannot be said to have a price. Slightly less than 20% of domestic production came from mines wholly or partly owned by Cleveland-Cliffs Inc. (Cliffs). Prices for that ore were unavailable. Prices may be available for the less than 1% of ore from mines owned by steel companies and Cliffs, but those prices would be representative of only a tiny portion of domestic production.

The average free-on-board mine value of usable ore shipped in 2000 was $25.57 per metric ton, slightly lower than that of 1999. This average value should approximate the average commercial selling price less the cost of mine-to-market transportation.

International iron ore prices rose in 2000. The price for Hamersley Iron Ore Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd. fine ores for fiscal year 2000 (April 1, 2000, to March 31, 2001) in the Japanese market was 27.35 cents per 1% Fe per long ton unit, up 4.4% compared with that of 1999 (Duisenberg, 2001, p. 46). The price for lump ore was settled at 36.26 cents per 1% Fe per long ton unit, an increase of 5.8 % compared with that of 1999. The lump ore to fine ore premium for Australian ore sold to Japan, increased from 8.2 in 1999 to 9.1 cents per 1% Fe per long ton unit. There were similar price percentage decreases in Europe. Iron ore prices have declined over the long term as well. The price of Carajás fines, a grade of ore produced by Companhia Vale do Rio Doce (CVRD) and sold to Europe, when denominated in U.S. dollars and adjusted for inflation using the U.S. Consumer Price Index for All Urban Consumers, fell by 33% between 1990 and 2000.

Transportation

Almost no iron ore is consumed near its source; most ores must be transported, often great distances. Nearly all iron ore leaves the mine by rail, after which much of it is transferred to ships. In the United States, a much larger proportion of ore is moved by water than in other countries because of the proximity of the mines to the Great Lakes, which offer low-cost transportation. No taconite mine is more than about 160 kilometers (km) from Lake Superior or Lake Michigan, and most are much closer. In 2000, 47.5 Mt of ore was moved on the Great Lakes, the equivalent of about 75% of domestic production. Iron ore constituted 47% of U.S.-flag cargoes, more than twice that of stone and gypsum, the next largest dry bulk material category shipped. Excluding transshipments, U.S.-flag carriers moved 53 Mt of iron ore in 2000.

Iron ore plays a more important role in Great Lakes shipping than is readily apparent. Significant quanities of coal and stone move via the Great Lakes, but they are generally backhaul cargoes. When a laker (ore carrier) moves an iron ore cargo to a steel mill, it often carries a stone or coal cargo on the way back to the iron ore ports of Lake Superior. Without iron ore to fill one leg of the voyage, freight rates would increase so much that railroads would capture much of these markets (Lake Carriers Association, oral commun., July 12, 2001).

The U.S. Congress passed and the President signed a bill providing funding for a new icebreaker for the Great Lakes. The $110 million contract for building the ship was expected to be let in July 2001, with the vessel scheduled to be working by 2005. The current icebreaker, the 56-year old Mackinaw, is well beyond its designed service life and is scheduled to be decommissioned in 2006 (Steve Kuchera, Duluth News Tribune, July 1, 2000, Senate funds new icebreaker—$110 million to go to Mackinaw replacement—U.S. Coast Guard's Great Lakes icebreaking capability replacement project, accessed July 5, 2000, at URL http://www.duluthnews.com/news/day4/dnt/local/ship.htm; Lake Carriers Association, oral commun., March 12, 2001).

The near drought conditions that have been causing low water levels in the Great Lakes since 1998 persisted through 2000. Lake Superior began the year at about 20 centimeters (cm) below the long-term average (LTA) and ended at about 38 cm below the LTA. The largest cargo shipped from Two Harbors in 2000 was 58,716 metric tons (t) compared with 62,559 t in 1998, an 8% drop. The average cargo shipped from Two Harbors for the same period fell by 7% (Lake Carriers Association, 2000).

The greatest financial loss caused by the low water levels was suffered by the shipping companies that transport iron ore on the Great Lakes. These companies enter into contracts with steelmakers to move a given quantity of ore at a certain price. Because of the low water levels, the ore boats must carry lighter loads to avoid running aground, so it takes more trips to carry a given quantity of ore. The shipping companies have not raised their rates to pass higher costs on to the steel companies because most of the steel companies are having financial troubles of their own.

Foreign Trade

Net imports, as usual responding strongly to the increase in consumption, rose 17%. U.S. exports of iron ore were less than 1% higher than those of 1999 (tables 9-15). U.S. net import reliance as a percent of apparent consumption of iron ore was 10% in 2000. Almost all exports consisted of pellets shipped via the Great Lakes to Canadian steel companies, which are partners in U.S. taconite projects in Michigan and Minnesota. U.S. imports of iron ore at 15.7 Mt, were 10% higher than those of 1999. Net imports, which averaged 11 Mt from 1989 through 2000, were 9.5 Mt in 2000. This was equivalent to 14% of U.S. ore consumption. Canada's share of U.S. imports was 51%; Brazil's was 39%.

World Review

The year 2000 was characterized as one in which major consolidation in the iron ore industry began. (See section below on Mergers and Acquisitions.)

Production.—World iron ore production was 1.1 Mt, a 4% increase compared with that of 1999 (table 17). Although iron ore production was widely distributed, taking place in about 48 countries, the bulk of world production came from just a few countries. The five largest producers, in decreasing order of production of gross weight of ore, were China, Brazil, Australia, Russia, and India. The United States and Canada were 6th and 8th. The top five accounted for 70% of world production.

China was the largest producer in gross weight of ore produced, but because its ore was of such low grade, the country's output ranked well below Australia's and Brazil's output in Fe content. Of the largest producing countries, India

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experienced the highest growth, increasing 7% over production in 1999.

Consumption.—World iron ore consumption, as indicated by the production of pig iron, DRI, and crude steel, reached record high levels. These are the chief indicators of iron ore consumption, with pig iron and DRI production being the more direct indicators. World pig iron production increased by 6% to 572 Mt. Asia's share of world pig iron production has consistently increased, rising from 35% in 1990 to 47% in 2000. In the same period, Europe's share fell from 24% to 21% and the former Soviet Union's share fell from 21% to 13%. DRI production increased by 12%, reaching 43 Mt in 2000.

World crude steel production grew by 7.4%, the largest such gain since 1973. The largest gains in production were in the countries of the former Soviet Union (14.4%), followed in decreasing order by Asia (7.5%), Western Europe (5.8%), and North America (3.9%). Six countries accounted for 57% of world crude steel production. From 1990 through 2000, Asia's share of world crude steel production rose from 31% to 39%. North America's rose from 14% to 16%. Europe's share fell from 28% to 25%. For the rest of the world as a whole, production share fell from 27% to 20%.

Trade.—In 2000, 46% of world iron ore production was exported, down from 47% in 1999. At 1,061 Mt, world exports increased by 11%. Australia was the leading exporter of iron ore, shipping 165 Mt to world markets, followed by Brazil, which exported 160 Mt, and India, which exported 35 Mt. Australia and Brazil continued to increase their domination of the global export market, with 67% of the total in 2000. In decreasing order of market share, Australia held 34%, Brazil 33%, India 7%, and Canada 5%. No other exporting country had as much as 5%. Western Europe and Asia accounted for 83% of world iron ore imports in 2000. Japan, as usual, was the leading importing country, accounting for 27% of imports. The next largest country was China, which imported 14%, followed by Germany at 10% and the Republic of Korea at 8%. Japan, China, and the Republic of Korea accounted for 50% of world iron ore imports in 2000.

Mergers and Acquisitions.—There was major merger activity in 2000 and it all, directly or indirectly, involved the two primary iron ore exporting countries, Australia and Brazil. Behind the trend was a need for iron ore producers to become larger to achieve economies of scale and to put themselves in a better bargaining position with individual customers who were themselves becoming larger through consolidation.

In August, Rio Tinto Ltd. completed a hostile takeover bid for North Ltd. of Australia and Canada (Kirk, 2000b). CVRD of Brazil was then and still is the world's largest iron ore producer. The next largest, situated in Western Australia, were the Broken Hill Pty. Co. Ltd. (BHP), Hamersley Iron Ore Pty. Ltd., a wholly owned subsidiary of Rio Tinto, and in Western Australia and Canada, North Ltd. As a result of the takeover, Rio Tinto, sole owner of Hamersley, became the second largest iron ore producer in the world followed by BHP. The North takeover bid came about a year after the collapse of Rio Tinto's negotiations with BHP over the pooling of the two companies' iron ore operations.

Anglo American plc, of London and Johannesburg, South Africa, made a counter bid. Anglo's offer was backed by the Japanese steel mills who were concerned that the consolidation of Western Australia's iron ore mining industry would weaken their bargaining position during price negotiations. The Japanese steel companies have long-term supply contracts with the three Australian mining companies, but renegotiate prices annually. In early August, Rio Tinto countered Anglo's bid and shortly thereafter North's directors recommended that shareholders accept Rio Tinto's increased bid.

Rio Tinto acquired a majority position in three large iron ore assets. Two of them are mining operations, Robe River Iron Associates in Western Australia and the Iron Ore Co. of Canada (IOC) in Canada. The third asset, the West Angelas deposit in Western Australia, was the primary target of Rio Tinto's interest in North Ltd. The West Angelas deposit is 300 km southeast of Robe River's port at Cape Lambert. In March 2000, the West Angelas Development was formally endorsed by the Western Australia Minister for Resources Development, enabling work to begin on the project The project has received all other Western Australian and Federal Government approvals. North had planned for production to begin in 2002 at a rate of 7 Mt/yr, rising to 20 Mt/yr in several years. Resources were reported to be at least1 billion tons, with 440 Mt of proven and probable reserves in two adjacent deposits. North expected that lump ore would comprise 33% of production. The development of West Angelas was underpinned by letters of intent from the Japanese steel industry to buy its production, one of the primary factors in Rio Tinto's decision to buy North. The tonnage to be purchased was to be 5 million dry long tons in 2002-03, increasing to 8 million dry long tons in the fourth year and thereafter. Construction contracts began to be let late in 1999, so that Robe River could meet customer demand for delivery in mid-2002.

Mergers in the mining industry generally do not have as much potential for synergy as they do in other industries because mining companies usually cannot share infrastructure. Mines cannot be moved, and most savings would come from consolidation of staffs. The Rio Tinto-North merger is a notable exception because the two companies can easily share infrastructure. The West Angelas deposit is about 50 km from Hamersley's rail line to Yandi. Thus, Rio Tinto could gain access to West Angelas by constructing a short spur rather than a 340-km rail line.

This acquisition resulted in a number of benefits to Rio Tinto. One of the more important benefits was that, as a result of acquiring very large iron ore deposit located close to its rail line, Rio Tinto should be able to make a major increase in its production rate with low production costs. It also boosted Rio Tinto's reserves. Another benefit was the addition of a port in Western Australia. The rail line from North's existing mine in Western Australia crosses the Hamersley rail line, and Rio Tinto could divert iron ore from Mesa J to Rio Tinto's own port at Dampier, providing greater flexibility. Hamersley also would probably be able to cancel, or postpone, the development of its Nammuldi Marra Mamba deposit because the West Angelas also has Marra Mamba type ore. Another benefit is that Rio Tinto's headquarters and North's main office are both in Melbourne, which would simplify the merger of corporate activities. One of the most important benefits is the increase in size. With the addition of IOC and Pannawonica, Robe River's iron ore mine in Western Australia, Rio Tinto has put itself in a better bargaining position. The beginning of production at West Angelas will enhance that position.

A possible disadvantage is the desire of the Japanese steel mills for a rail line between West Angelas and the Hamersley-Robe River rail crossing about 70 kilometers from Cape Lambert. The Japanese steel mills say that there is a strong

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likelihood that production at the West Angelas Mine could increase to 40 Mt/yr to 50 Mt/yr, and a new rail line would be required to handle it. Under the terms of the Robe River joint-venture agreement, which governs the West Angelas project, Rio Tinto will be unable to reverse the unanimous decision to develop the West Angelas project, inclusive of the new railway construction, as per the resolution dated March 6, 2000. Seen as a whole, the benefits to Rio Tinto far outweigh the disadvantages. If Rio Tinto follows North's expansion plans of producing 20 Mt/yr from West Angelas and 45 Mt/yr from Pannawonica by 2010, Rio Tinto could be producing 104 Mt/yr by the end of the decade (Metal Bulletin, 2000u). The near-term effect was that Rio Tinto's iron ore production rose 40%, increasing from 51.8 Mt in 1999 to 72.5 Mt in 2000 (Metal Bulletin, 2001).

Late in the year, Rio Tinto announced that it intended to raise its stake in IOC from 56.1% to 75% by making a $266 million ($8.90 per unit) offer to Labrador Iron Ore Royalty Income Fund. The fund owns an 18.9% stake in IOC through its wholly owned subsidiary Labrador Mining and Exploration Co. Ltd. The remaining 25% in IOC is held by Mitsubishi. The offer, which is being made through Rio Tinto's wholly owned subsidiary, Rio Tinto Canada Inc., was to be conditional on the acceptance of 75% of the unit-holders and regulatory approval (Rio Tinto, December 15, 2000, Offer for Labrador iron ore Royalty Fund, Media Release, accessed on February 15, 2001, at URL www.riotinto.com/utilities/search/ShowPressRelease.asp?PDFNumber=316&Keywords='iron%20orre'&PDFDocType=P).

Billiton plc, the large London-based mining and metals company, bought a 2.1% indirect interest in CVRD. The $327 million deal, Billiton's first venture in the iron ore industry, bought the company a 66.97% share in Sweet River Investment Ltd., provided Billiton with 7.74% share in Valepar SA. Valepar was established in 1997 to participate in the privatization of CVRD by the Brazilian Government and holds a 27% interest in CVRD and a 42% voting interest, which effectively made them the controlling shareholder. The transaction gave Billiton a seat on Valepar's executive board (Kepp, 2000d; Kohl, 2000; Mining Journal, 2000a).

On May 11, CVRD purchased Mineração Socoimex S.A. (Socoimex) whose main iron ore mine, the Gongo Soco Mine is located along the CVRD-owned Vitoria Minas railroad. The mine reportedly has proven reserves of 75 Mt of high-grade hematite and 30 Mt of itabirite. Socoimex has been producing 7 Mt/yr of sinter seed, pellet feed, and lump ore for the domestic market and Europe (Metal Bulletin, 2000g; TEX Report, 2000d; Companhia Vale do Rio Doce, May 15, 2000, CVRD acquired SOCOIMEX, accessed August 24, 2000, via URL http://www.cvrd.com.br/ing/infofin/e_infofin.htm).

On May 30, CVRD purchased 63% of S.A. Mineração Trinidade - Samitri (Samitri) from the Luxembourg-based Arbed Group. The sale was part of Arbed's plan to focus on its core steelmaking business, through the divestment of noncore assets. In September, CVRD made an offer to the minority shareholders, which resulted in the acquisition of 36% of the remaining shares, raising CVRD's ownership of Samitri to 99%. Samitri owned four mines in Minas Gerais, as well as 51% of Samarco Mineração S.A., with BHP holding the remaining 49%. BHP and CVRD agreed to enter a joint venture to rationalize the Alegria Iron Ore Complex in Brazil. The companies agreed that BHP would acquire a further 1% holding in Samarco to equalize its ownership with Samitri at 50-50. Samitri and Samarco have iron ore mining and processing facilities in the Alegria Complex. The agreement between BHP and CVRD was to facilitate the restructuring of Samitri and Samarco operations aimed at increased efficiencies, reducing costs, and improving Samarco's product quality.

Samitri's mines, Alegria, Andrade, Corrego do Meio, and Morro Agidu, are in the Brazilian State of Minas Gerais. Prior to the sale of Samitri to CVRD, the Andrade Mine was sold to Arbed's Brazilian steel subsidiary Companhia Siderúrgica Belgo Mineira. Samitri's production capacity is 17.5 Mt/yr. Their products include sinter feed, concentrate, and lump, most of which are moved by rail under contract with CVRD to the port of Tubarão. Samarco's assets include a mine and concentrating plant near Alegria and a pellet plant and port at Ponta Ubu. They are linked by a 396-km slurry pipeline. Samarco recently doubled its pellet production capacity to 12 Mt/yr and plans to invest $126 million through 2002 for a further expansion to 14 Mt/yr. Most of the increased production will be sent to Asia. Part of the investment will be spent on a hydroelectric plant to help make Samarco self-sufficient in energy (Kepp, 2000c; Mining Journal, 2000b; TEX Report, 2000b; Jones, 2001; BHP Ltd., May 31, 2000, BHP and CVRD enter agreement to rationalise the Alegria iron ore complex in Brazil, accessed February 18, 2000, at URL http://www.bhp.com/default.asp?page=62&file=newscentre/pressarchive/20000531a.asp; Companhia Vale do Rio Doce, written commun., November 22, 2000; Companhia Vale do Rio Doce, written commun., March 19, 2001).

On October 9th CVRD through Itabira Rio Doce Co. Ltd., a wholly owned subsidiary, purchased one-half of the 4-Mt/yr pellet plant in Bahrain. CVRD, with joint-venture partner and investment bank Gulf Investment Corp., paid $183 million. The plant has its own port capable of taking ships of 100,000 deadweight tons (dtw), and a thermoelectric powerplant. CVRD already supplies most of the plant's pellet feed. About 75% of the plant's output is for the direct reduction market (Metal Bulletin, 2000f; i; Cia.Vale do Rio Doce, October 6, 2000, CVRD acquires pelletizing plant in Bahrain, accessed February 27, 2001, at URL http://www.cvrd.com.br/ing/e_mapadosite.htm).

CVRD and a group of institutional investors acquired Ferrovia Centro-Atlântica (FCA), the largest railroad in Brazil. FCA has 7,080 km of track and its own fleet of 270 locomotives and 8,400 railcars. It connects the iron ore mines in Minas Gerais to the port of Tubarão [Cia. Vale do Rio Doce, January 24, 2000, Ferrovia Centro-Atlântica (FCA), accessed February 27, 2000, at URL http://www.cvrd.com.br/ing/e_mapadosite.htm].

In the space of 5 months, CVRD acquired the whole of two iron ore producers and one-half of a third. In doing so it has increased its production capacity by more than 30 Mt/yr. It has also increased its jointly held pellet production capacity by 14 Mt/yr, a gain of 56%. Its reserves have increased considerably. The company has solidified its position as the world's largest iron ore producer.

Among the effects of these acquisitions are the following: Two of the three iron ore producers (CVRD and Rio Tinto) became larger; with the third largest (Rio Tinto) becoming the second largest. The consolidations will provide CVRD and Rio Tinto with more leverage in price negotiations. Both companies should be in better positions to reduce costs. A major

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greenfield project will be developed. Deposits of other companies stand a better chance to be developed. With the big three in Western Australia becoming the big two, deposits such as Hope Downs are more likely to be funded because they could provide competition to Rio Tinto and BHP.

Australia.—(See also earlier section on Mergers and Acquisitions.) BHP announced that it had decided to raise production at its Yandi Mine in the Pilbara region of Western Australia because of continued strong demand for its fines. The company intends to increase production from 25 Mt/yr to 30 Mt/yr. The increase is to be achieved with only minor modifications to existing operations. BHP also intends to introduce a new higher value product: Yandi lump, a pisolitic iron ore. Trial with the Yandi lump began during the year in cooperation with the Japanese steel mills. Four mining campaigns have produced 375,000 t of Yandi lump for shipment to Japan, and BHP has decided to extend the trial mining for another year (Metal Bulletin, 2000a).

In 1999, BHP offered its 1,000 employees at its Pilbara iron ore operations in Western Australia individual staff contracts to replace the existing employee contracts between the company and labor unions. The object of these contracts was to broaden the range and type of work being done by employees to increase productivity (Kirk, 2001, p. 41.4).

Staff contracts have been the norm at competing iron ore producers—at Robe River since the 1980s, and at Hamersley since the mid-1990s (Metal Bulletin, 2000b). The old contracts negotiated with the unions could have put BHP at a competitive disadvantage with the other two major Western Australia iron ore producers. Workers held a one-day strike in December 1999 to protest BHP's tactics, and the labor unrest continued into the new year (Mining Journal, 1999). The Australian Council of Trade Unions began legal action against the company, alleging that BHP's strategy of offering staff contracts was unlawful (Mining Journal, 2000c). The Australian Federal Court issued an injunction on January 31 against BHP, preventing the company from offering and entering into individual contracts with members of its Pilbara workforce. At yearend, the situation remained unresolved.

Strong demand for Marra Mamba type iron ore has heightened the prospects for BHP to develop its Mining Area C (MAC) deposit near the Yandi Mine. Full capacity of 15 Mt/yr at the $80-million project could be reached by 2010, although there is potential to increase production to 20 Mt/yr. A $70-million rail line will link MAC to the Yandi Mine. Another $11 million will be needed to upgrade the rail network that links BHP's mines to its port at Port Hedland. If production is boosted to 20 Mt/yr, BHP would have to use larger locomotives capable of hauling more than 300 railcars compared with 100 currently (Hagopian, 2000).

Hamersley received approval from the Western Australia Government to increase production capacity at the Yandi Mine from 15 Mt/yr to 20 Mt/yr. No major changes to the existing facilities are planned. The capacity increase will be achieved by plant modifications that will allow annual planned operating hours and throughput rates to be increased (Engineering and Mining Journal, 2000). The Hamersley port expansion and upgrade of the existing Parker Point and East Intercourse Island facilities have been substantially completed. The combined capacity has been increased from 55 Mt/yr to 70 Mt/yr (Western Australia Department of Resources Development, [undated], Commissioned projects (for financial year 1999-2000), accessed March 16, 2000, via URL http://www.drd.wa.gov.au/search/index.htm).

Portman Mining Ltd., which changed its name to Portman Ltd., was mining on Cockatoo Island, off the coast of Western Australia (TEX Report, 2000h). Cockatoo Island had been previously mined by BHP. Portman was treating waste stockpiles and producing a concentrate. That operation was closed, and Portman began mining a 1.6-Mt high-grade hematite deposit at the eastern end of the pit that had been covered by infrastructure facilities. The first shipment of ore from the new operation was made on September 10. The guaranteed specifications of the ore are a minimum 68% Fe and maxima of 1.5% silica, 0.75% alumina, and 0.01% phosphorus. The company expects the mine to have a life of 2 years (Metal Bulletin, 2000e, f; Portman Mining Ltd., February 9, 2000, Portman extends Cockatoo Island output, accessed February 10, 2001, via URL http://www.portman.com.au/html/frames.htm).

At the Koolyanobbing Mine, Portman plans to increase production from the current level of 2 Mt/yr to 3.5 Mt/yr in 2001 and to 6 to 8 Mt/yr over the next 5 years. The expansion includes the opening of an additional storage facility at the port at Esperance, which was completed in July 2000, and the delivery of 50 new railcars. An additional 80 ore cars of a new lighter weight design have been ordered to handle the expansion to 3.5 Mt (Metal Bulletin, 2000m, v, x; Portman Mining Ltd., November 3, 2000, Portman moves ahead with next phase of Koolyanobbing expansion, accessed November 20, 2000, via URL http://www.portman.com.au/html/frames.htm; Portman Mining Ltd., March 11, 2000, Government approval received for dredging of Esperance Harbor, accessed November 20, 2000, at URL http://www.portman.com.au/asp/frames.asp?newsItem=43&news Title=ASX+ANNOUNCEMENTS).

A three-stage dredging program at Esperance will allow the full loading of capesize vessels (those too large to transit the Panama Canal) of as much as 180,000 dwt by the third quarter of 2001. The Western Australia Government has committed itself to the construction of a new shiploader and upgrading of the railway system, which will allow Portman to increase annual production to about 5 Mt/yr. The ability to fully load capesize vessels is expected to lower Portman's seaborne freight rates. Portman's plans also include an A$6 million exploration and development program to evaluate its recently acquired Mt. Jackson, Bungalbin, and Windarling deposits north of the Koolyanobbing operation (Metal Bulletin, 2000d).

The Robe River Mining Co. Pty. Ltd. participants approved the construction of a second mine tailings processing plant. The plant is to have a feed capacity of 7.9 Mt/yr, which is higher than that of the existing plant. The processing plant converts material previously regarded as waste to a salable product by removing clay. The plant is expected to increase the mine's reserves, reduce the stripping ratio, and extend the life of the Mesa J operation by 1½ years. The first process plant, which was commissioned last year, has performed at better than planned recovery rates and will receive minor upgrades to increase its feed capacity to 5.2 Mt/yr (TEX Report, 2000c, g; North Ltd., January 16, 2000, Robe ships 500 million tonne, accessed February 15, 2000, at URL http://www.north.com.au/news-releases/rel-2000011700.html).

ABM Mining Ltd., formerly Australian Bulk Minerals, was to have merged with Ivanhoe Mines Ltd. late in the year. ABM bought the Savage River iron ore operation from the Tasmanian Government in 1997. In 1999, ABM produced 2 Mt of pellets

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and 48,000 t of concentrate. In September, ABM started the fifth production line in the pellet plant, which is expected to raise pellet production to 2.5 Mt/yr. An expansion project is underway that is expected to raise production to 2.95 Mt/y (Mining Journal, 2000e; TEX Report, 2000a).

Brazil.—(See also earlier section on Mergers and Acquisitions.) CVRD announced a budget of $589 million for its iron ore operations for 2000, 63% of its overall budget (Kepp, 2000b; Metal Bulletin, 2000h). Most of the funds ($410 million) were allocated for the construction of the 6-Mt/yr pellet plant located at São Luìs in northern Maranhão State (Metal Bulletin, 2000j). About $285 million was to be spent on the plant itself and $125 million on the mine, railway, and port infrastructure. Construction began in the first half of the year. Although this will be CVRD's eighth pellet plant, it will be the first to use ore from Carajás, which is in the northern system. It will be similar to the southern system in that the ore will be moved by rail from several hundred kilometers inland to a pellet plant at or near a port from which iron ore is shipped. The plant initially will produce DRI pellets. The plant is to be wholly owned by CVRD, and when it reaches full capacity it will increase the capacity of CVRD's two other wholly owned plants and five joint venture plants to 31 Mt/yr. The plant, scheduled to begin production in mid-2002, will use Lurgi Metallurgie technology.

Other funds were to be used to begin increasing capacity at CVRD's Brucutu Mine in Minas Gerais, which currently produces 2 Mt/yr. The mine was expected to begin producing at a rate of 6 Mt/yr by 2005, eventually reaching a capacity of 24 Mt/yr. Another $30 million was to be spent on expanding the Carajás beneficiation plant and adding to the excavator fleet. The beneficiation plant at Carajás is used to wash, crush, and screen the ore. The ore does not need to be concentrated because of its high Fe content of 67%. Funds were to be directed toward the construction of two hydroelectric dams that are expected to lower operating costs. The southern system rail line was to receive funds to purchase new locomotives.

CVRD announced plans to automate the seven pellet plants at Tubarão in the southern system. Although this $23-million project will result in a marginal increase in capacity, its primary goal is to improve pellet quality, reduce production costs by 20 U.S. cents per ton, and cut the pellet rejection rate. The system will be introduced in three stages: first in field instrumentation, including sensors and measures; second in new software to control and supervise the pelletization process; and third in optimizing control of all processes, principally in energy-intensive areas such as ore crushing and pellet induration. The 4-year project will begin with CVRD I and II plants, which are wholly owned by CVRD and are more than 30 years old (Kinch, 2000; Metal Bulletin, 2000d; Companhia Vale do Rio Doce, written commun., March 19, 2001).

Mineraçãoes Brasileiras Reunidas S.A. (MBR) plans to spend $240 million over the next 2 years to increase the company's production capacity from its current 26.5 Mt/yr to 32 Mt/yr. Some of the funds will go into building a new beneficiation plant to handle the increased production from MBR's new mines, Tamandua and Capito do Mato. The production is to offset the production lost when the Aguas Claras and Mutuca Mines are depleted. In addition, the terminal at the port of Septiba will receive a new stacker-reclaimer (Kepp, 2000a).

Canada.—(See also earlier section on Mergers and Acquisitions.) The Board of Directors of IOC announced on June 30 that it had approved the refurbishment and reactivation of its pellet plant in Sept-Iles at a cost of $254 million, some of which had already been spent on engineering and evaluation studies. Closed since 1982, the refurbished plant is expected to be commissioned in June 2002. Initial production rate in the second half of 2002 is expected to be 1.3 Mt, with full production of 4.5 Mt of high-quality blast furnace pellets being achieved in 2003. The pellets will be mainly for North American and European steel mills. This increased production rate is expected to lift pellet production at IOC to 17 Mt/yr and take nearly all of IOC's production through to pellet form.

IOC selected Svedala Industri to supply engineering, equipment, and services for the reactivation of the plant. Svedala Pyro Systems USA, which will provide services throughout the construction and startup phases of the project, has already begun work. IOC also announced that it was to buy 12 new haul trucks for the mine (Metal Bulletin, 2000ab; Mining Journal, 2000f; g; Iron Ore Co. of Canada, June 30, 2000, Iron Ore Co. of Canada announces reactivation of its Sept-Iles pellet plant, accessed March 7, 2001, at URL http://www.ironore.ca/overview_1.htm).

China.—Officials at the State Administration for the Metallurgical Industry (Sami) expected to import about 65 Mt of iron ore in 2000, about 4 Mt more than in 1999. Their target for pig iron production for the year was 111.4 Mt, and their expected domestic production of 240 Mt of iron ore would only yield 73.6 Mt of pig iron because of the low Fe content of Chinese ore. It takes 3.26 t of Chinese ore to produce 1 t of pig iron; thus, China would need to import some 65 Mt of higher yield ore to produce the remaining 37.8 Mt of pig iron (Metal Bulletin, 2000c). A study by Sami concluded that China should invest further in overseas iron ore mines to raise the proportion of imports from Chinese joint-venture mines from the current 12% to 50%.

China is the world's largest steel producer, with output exceeding 100 Mt/yr in each of the past 5 years, but still must import about 10 Mt/yr of steel to meet domestic needs. There are two overseas investments in iron ore: China Metallurgical Import & Export Corp.'s 40% ownership of the Channar Mine in Australia and Shougang Corp.'s 100% ownership of the Marcona Mine in Peru (Metal Bulletin, 2000w).

India.—Arrangements were being made to ship ore from the port of Haldia near Calcutta, and the Government was planning to build a new port at Dhamra, 70 km south of Paradeep in Orissa. Iron ore production costs in India are relatively low, but transportation costs are high. In Goa, the distance from mine to port is 50 km, but other major mines have to transport their ore long distances to the ports for export. The new port at Dhamra will reduce this distance. Once the ore arrives at a port, there are further problems due mainly to poor port handling facilities, according to Indian Ministry of Mines officials. Nearly all leading ports around the world have loading rates approaching 100,000 metric tons per day (t/d). Indian ports achieve a maximum of 40,000 t/d. It was estimated that shipping ore in 300,000-dwt vessels loaded at 100,000 t/d could achieve a total freight savings of $5 per ton (Metal Bulletin, 2000y; Raghuvanshi, 2000b; TEX Report, 2000e).

The State Government of Karnataka decided to extend by a year the work permit given to Kudremukh Iron Ore Co. (KICOL). KIOCL's 30-year mining lease was due to expire on July 24. The company was granted a 1-year work permit so that mining operations could continue. The issue preventing the

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long-term lease being granted was the State government's designation of a 500-square kilometer park, which includes the mining leases and all of KIOCL's operations. The company was asked to confine its operations to an area of about 1,400 hectares and not the 4,600 hectares that KIOCL had sought. KIOCL's request for a long-term lease of 20 years will await studies of the environmental impact of the mine (Metal Bulletin, 2000s).

Mineral Sales Pvt. Ltd. (MSPL) plans to sell 2.5 Mt of ore in 2000-01. The company plans to increase production at all its mines, to reach 4.5 Mt/yr to 5 Mt/yr of ore by 2003-04. MSPL has been acquiring new mines to aid in this increase (Metal Bulletin, 2000n).

Jindal Vijayangar Steel plans to open its new iron ore mine. The mine is expected to produce about 1.8 Mt/yr of ore, rising to 3 Mt/yr when full production is reached. The ore will feed the company's new 3-Mt/yr pelletizing plant (Metal Bulletin, 2000r).

Construction was started on the second phase of development for Hy-Grade Pellets Ltd., which will add an 8-Mt/yr beneficiation plant and a 267-km slurry pipeline to the existing 3.3-Mt/yr pelletizing plant. Hy-Grade pellets is a joint venture between the United Kingdom-based steel trading group, Stemcor Holdings, and Essar Steel Ltd. of India, on a 51-49 basis, respectively. Essar Steel entered into a 20-year purchase agreement with the new company. Completion of the plant, which is expected to take 14 to 18 months, will enable Hy-Grade to produce pellets with an Fe content of 68.5%, up from the current level of 67%. The company is also considering increasing pellet capacity to 7 Mt/yr. The pellet plant is near the Visakhapatnam Port Trust and has access to mechanized shiploading facilities capable of handling capesize vessels. More than 30 Mt of iron ore fines lying at the mine head in Bailadila will be beneficiated and transported by slurry pipeline to the pellet plant (Metal Bulletin, 2000l; Raghuvanshi, 2000a).

Some of the smaller iron ore mines in the Indian State of Goa may be forced to close because of rising costs and an increasing tax burden, according to industry officials. Miners are challenging a proposal by the Marmugoa Port Trust to raise cargo-related charges by 25% and are criticizing the State's plan to impose a levy on mining to raise funds for environmental restoration of mine sites. Iron ore companies were also facing a demand to pay tax on their exports for the first time. Mining companies in Goa, particularly iron ore producers, which have enjoyed total tax exemptions on their exports since 1991, will have tax on their earnings introduced in a phased manner. In the first year, 20% of their income will be taxed; the rest will be taxed in 20% increments per year for 4 years until all export income is taxed (Metal Bulletin, 2000aa, o, z).

Ten companies, seven of them international firms, responded to an expression of interest for joint-venture participation for mine development with Indian Iron and Steel Co. (Iisco), a wholly owned subsidiary of state-owned Steel Authority of India Ltd. (Sail). The Indian Government announced that it had written off $391 million in loans and advances to Iisco from Sail. Part of the attraction to Iisco is its rich iron ore resources, reportedly measured in billions of tons. The company's Chiria iron ore deposits are the largest in India (Raghuvanshi, 2000c).

Iran.—National Iranian Steel Co. (Nisco), the primary steel producer, set as a goal the production of 7 Mt of steel for 2000, with plans for a further increase to 10 Mt by 2005. Nisco's principal iron ore mine is at Tchogart. It provides at least 5 Mt/yr of lump ore (56% to 60% Fe) to the steelworks at Isfahan. The construction of a new $115-million ore processing plant was proceeding. At Nisco's Gol-e-Gohar Mine, Voest-Alpine Industrieanlagenbau, the Austrian construction firm, is expanding the beneficiation plant to increase capacity from the existing capacity of 3.5 Mt/yr to 5.2 Mt/yr. The project was expected to be completed in 18 months. Elsewhere in the iron ore sector, development is proceeding at the Sangan deposit in eastern Iran, which was expected to produce at an annual rate of 3.4 Mt of concentrates within a few years (Metal Bulletin, 2000p; Mining Journal, 2000g).

South Africa.—The iron ore division of Iscor Ltd. was studying the development of a new mine at a location 60 km south of its existing Sishen Mine. A recent drilling program has shown that the Welgevonden deposit is more promising than had been previously thought and is a potential replacement for the Thabazimbi Mine. Iron ore reserves at Thabazimbi are forecast to be depleted in 2006 to 2007 (Metal Bulletin, 2000t; TEX Report, 2000f).

Venezuela.—CVG Ferrominera Orinoco was expecting iron ore sales to rise to 27 Mt/yr by 2004, with most of the increase coming from the domestic market. This will require Ferrominera to invest in its mines, processing, and transport facilities. The company intends to install 12 Mt of new concentration capacity. This is expected to take place in two stages. Ferrominera was close to selecting a contractor to build the first two of three modules, which are expected to be in place by the second half of 2003. The company also intends to raise its pellet plant capacity to 4 Mt/yr (Metal Bulletin, 2000k).

Outlook

Mergers and acquisitions are expected to cause major changes in the structure of the iron ore industry in the near term. Iron ore prices have been declining for some time and there is no reason to believe that this trend will not continue. (See earlier section on Prices.) Thus, iron ore producers must find ways of making profits other than raising prices. As the producers operate in an increasingly global economy, there will be pressure to reduce production costs; one way of doing this is by mergers and acquisitions. Mergers in the mining industry, however, generally do not have as much potential for synergy as they do in other industries. Mining companies usually cannot share infrastructure because mines cannot be moved. Synergy can be achieved by the industry by the consolidation of corporate and other activities.

The domestic iron ore industry is totally dependent on the steel industry for sales. This dependence is not expected to change in the near future. Information about steel industry trends is provided in the outlook section in the Iron and Steel chapter of the 2000 USGS Minerals Yearbook. For the near term, growth of the U.S. iron ore industry is tied to the growth of the integrated steelworks along the Great Lakes. Significant expansion in the domestic iron ore industry may be possible if one or more direct-reduction processes prove to be economic for existing and potential Great Lakes producers. If this occurs, the industry can supply the rapidly expanding minimill sector of the U.S. steel industry. Steel products require lower residual alloy content than can be readily achieved with scrap. This indicates a role for imported DRI in the coastal regions of the United States and domestically produced DRI further inland where cheaper power is available. However, no matter how

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spectacular DRI growth is during the next decade, it will not be able to replace more than a fraction of the world's blast furnace production because of technological restrictions. The blast furnace is expected to remain the mainstay of the iron and steel industries in most developed countries during the next 25 years.

Based on recent growth rates in Asia, additional iron ore production capacity will be needed there and in other countries. As in the United States, much of the increase in consumption of iron in Asia will be from newly constructed minimills, but unlike the United States, where the consumption of iron ore in blast furnaces is declining, much of the additional ore needed will go to feed blast furnaces.

References Cited

American Iron and Steel Institute, 2000, Annual statistical report: American Iron and Steel Institute, 130 p.

American Iron Ore Association, 2000, Statistical report: American Iron Ore Association, 58 p.

Duisenberg, Hennie, 2001, Iron ore statistics: United Nations Conference on Trade and Development, Trust Fund Project on Iron Ore Information, August, 99 p.

Engineering and Mining Journal, 2000, In the Pacific—Australia: Engineering and Mining Journal, v. 200, no. 10, October, p. WW14.

Hagopian, Arthur, 2000, Demand for iron ore increases prospects for Australian project: American Metal Market, v. 108, no.199, October 16, p. 6.

Jones, Bob, 2001, Samitri studies future with Samarco: Metal Bulletin, no. 8469, April 20, p. 25.

Kepp, Michael, 2000a, Brazil's MBR planning to spend $240M to boost iron ore output: American Metal Market, v. 108, no. 63, April 3, p. 10.

———2000b, CVRD on big spending spree: American Metal Market, v. 108, no. 13, January 21, p. 1, 16.

———2000c, Samarco pegs $126M to hike pellet output: American Metal Market, v. 108, no. 203, October 20, p. 4.

———2000d, Why Billiton is buying a slice of the world's biggest iron ore producer: American Metal Market, v. 108, no.146, July 31, p. 10.

Kinch, Diana, 2000, Strong markets prompt CVRD to boost mine output: Metal Bulletin, no. 8475, May 15, p. 26.

Kirk, W.S., 2000a, Iron ore in March 2000: U.S. Geological Survey Mineral Industry Surveys, June, 8 p.

———2000b, Rio Tinto acquires North: Skillings Mining Review, v. 89. no. 39, September 23, p. 4-7.

———2001, Iron ore, *in* Metals and minerals: U.S. Geological Survey Minerals Yearbook 1999, v. 1, p. 41.1-41.19.

Kohl, Christian, 2000, Billiton gains toehold in Brazil's CVRD: American Metal Market, v. 108, no.144, July 27, p. 7.

Lake Carriers Association, [2001], 2000 Annual report: Lake Carriers Association, 67 p.

Metal Bulletin 2000a, BHP raises output at Yandi: Metal Bulletin, no. 8489, July 3, p. 20.

——— 2000b, China shifts policy on joint ventures abroad: Metal Bulletin, no. 8488, June 29, p. 19.

———2000c, Chinese ore mines struggle to meet demand: Metal Bulletin, no. 8460, March 20, p. 31.

———2000d, Contract signed to automate Tubarão pellet plants: Metal Bulletin, no. 8508, September 14, p. 19.

———2000e, Court stops BHP offering staff contracts: Metal Bulletin, no. 8487, February 3, p. 21.

———2000f, CVRD completes pellet plant acquisition: Metal Bulletin, no. 8516, October 12, p. 21.

———2000g, CVRD completes takeover of Socoimex: Metal Bulletin, no. 8476, May 18, p. 19.

———2000h, CVRD plans record investment spending: Metal Bulletin, no. 8444, January 24, p. 19.

———2000i, CVRD poised to win Bahrain pellet plant: Metal Bulletin, no. 8508, September 14, p. 19.

———2000j, CVRD sets 2000 start-up of new pellet plant: Metal Bulletin, no. 8466, April 10, p. 31.

———2000k, Ferrominera must expand to serve home market: Metal Bulletin, no. 8468, April 17, p. 27.

———2000l, Hy-Grade breaks ground on phase two expansion: Metal Bulletin, no. 8482, June 8, p. 31.

———2000m, India move to step up exports of iron ore: Metal Bulletin, no. 8501, August 17, p. 20.

———2000n, Indian miners to pursue direct exports: Metal Bulletin, no. 8474, May 11, p. 33.

———2000o, Indian ore miners lose tax exemptions: Metal Bulletin, no. 8459, March 16, p. 21.

———2000p, Iron and steel—In brief: Metal Bulletin, no. 8496, July 27, p. 22.

———2000q, Ispat goes electric at Inland: Metal Bulletin, no. 8473, May 8, p. 23.

———2000r, Jindal nears start of mining and pellet production: Metal Bulletin, no. 8529, November 27, p. 23.

———2000s, Kudremukh gets one-year extension: Metal Bulletin, no. 8495, July 24, p. 22.

———2000t, New Sishen deposit may aid Iscor expansion: Metal Bulletin, no.8520, October 26, p. 20.

———2000u, North aims for 70 tonnes production by 2010: Metal Bulletin, no. 8452, February 21, p. 24.

———2000v, Portman boosts iron ore sales: Metal Bulletin, no. 8505, September 4, p. 20.

———2000w, Portman expands output at Cockatoo Island: Metal Bulletin, no. 8450, February 14, p. 29.

———2000x, Portman to gain 100% of iron ore project: Metal Bulletin, no. 8445, January 27, p. 22.

———2000y, Rail limits hit Portman iron ore shipments: Metal Bulletin, no. 8473, May 8, p. 24.

———2000z, Rising costs may force Goa mines to close: Metal Bulletin, no. 8473, May 8, p. 26.

———2000aa, Sept-Iles to go ahead: Metal Bulletin, v. 8524, November 9, p. 12.

———2001, Rio Tinto iron ore output soars 40%: Metal Bulletin, no. 8545, January 29, p. 23.

Mining Journal, 1999, BHP iron ore shipments disrupted: Mining Journal, v. 333, no. 8562, December 17, p. 483.

———2000a, Billiton buys seat at CVRD's table: Mining Journal, v. 335 no. 8593, July 28, p. 71.

———2000b, Brazilian iron sector shake-up: Mining Journal, v. 334, no. 8535, June 2, p. 425.

———2000c, Injunction stops BHP contracts: Mining Journal, v. 334, no. 8568, February 4, p. 91.

———2000d, Iran keen for business—More iron ore: Mining Journal, v. 334, no. 8588, June 23, p. 482,483.

———2000e, Ivanhoe to take over iron ore producer: Mining Journal, v. 334, no. 8589, June 30, p. 509.

———2000f, North to reopen Sept-Iles: Mining Journal, v. 335, no. 8590, p. 3.

———2000g, Svedala to supply IOCC pellet plant: Mining Journal, v. 335, no. 8614, p. 492.

Raghuvanshi, Vivek, 2000a, Hy-Grade to double iron ore pellet capacity: American Metal Market, v.108, no. 49, March 14, p. 12.

———2000b, Indian iron ore exports stalled at docks: American Metal Market, v. 108, no. 161, August 21, p. 4.

———2000c, Sail inundated with offers for Lisco revival partnership: American Metal Market, v. 32, no. 7580, June 23, p. 4.

TEX Report 2000a, ABM and avanhoe to be integrated by year end: TEX Report [Tokyo], v. 32, no. 7703, December 21, p. 4.

———2000b, Arbed more focused on steel business by the sale of non-core business: TEX report, [Tokyo], v. 32, no. 7565, June 2, p. 2.

———2000c, Australian North's effort at cost efficiency boosts iron ore productivity: TEX Report [Tokyo], v. 32, no. 7595, July 14, p. 8.

———2000d, Brazil's CVRD acquires Socoimex: TEX Report, [Tokyo], v. 32, no. 7553, May 17, p. 2.

———2000e, India to build a new iron ore shipping port in Orissa: TEX Report [Tokyo], v. 32, no. 7488, February 9, p. 9.

———2000f, Iscor to implement feasibility study on development of new mine: TEX Report, [Tokyo], v. 32, no. 7655, October 12, p. 4.

———2000g, Party held to mark Robe River's 500 millionth ton shipment: TEX Report [Tokyo], v. 32, no. 7548, May 10, p. 16.

———2000h, Portman Mining Limited has name changed: TEX Report [Tokyo], v. 32, no. 7540, April 24, p. 6.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iron. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Iron Ore. Ch. in Metal Prices in the United States Through 1998, 1999.

Digitized by Google

Iron Ore. Ch. in Mineral Commodity Summaries, annual.
Iron Ore. Mineral Industry Surveys, monthly.

Other

American Iron and Steel Institute (Washington, DC).
American Iron Ore Association (Cleveland, OH).
American Metal Market (New York daily paper).
Association of Iron and Steel Engineers (Pittsburgh, PA).
Company annual reports to stockholders and 10-K reports to Securities and Exchange Commission.
Engineering and Mining Journal.
Institute on Lake Superior Geology (Houghton, MI).
International Iron and Steel Institute (Brussels).
Iron and Steel Society (Warrendale, PA).
Iron ore. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Lake Carriers' Association (Cleveland, OH).
Metal Bulletin (London) and Iron Ore Databook.
Mining Journal (London) and Mining Annual Review.
Natural Resources Canada.
Roskill Information Services Ltd. Reports (London).
Skillings Mining Review.
State of Minnesota:
Mining Tax Guide, annual.
Minnesota Mining Directory, annual.
The TEX Report (Tokyo daily bulletin) and Iron Ore Manual, annual.
United Nations Conference on Trade and Development (Geneva):
Intergovernmental Group of Experts on Iron Ore.
Trust Fund Project on Iron Ore Information.
U.S. Department of Energy, Energy Information Administration.
U.S. Department of Labor, Mine Safety and Health Administration.
U.S. Department of State, unclassified dispatches.

TABLE 1
SALIENT IRON ORE STATISTICS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Iron ore (usable, less than 5% manganese): 2/					
Production	62,083	62,971	62,931	57,749	63,089
Shipments	62,200	62,800	63,200	58,500 r/	61,000
Value	$1,750,000	$1,860,000	$1,970,000	$1,550,000	$1,560,000
Average value at mines, dollars per ton	$28.07	$29.60	$31.14	$26.47	$25.57
Exports	6,260	6,340	6,000	6,120	6,150
Value	$232,000	$235,000	$245,000	$243,000	$246,000
Imports for consumption	18,400	18,500	16,900	14,300	15,700
Value	$556,000	$547,000	$517,000	$399,000	$420,000
Consumption (iron ore and agglomerates)	79,600	79,500	78,200	75,100	76,500
Stocks, December 31:					
At mines, plants and loading docks 3/	4,650	4,860	6,020	5,710	9,150
At receiving docks 4/	2,250	2,880	4,080	2,770	2,860
At consuming plants	18,800	20,200	20,500	17,900	16,800
Total 5/	25,700	27,900	30,600	26,400	28,800
World, production 6/	1,018,436 r/	1,068,727 r/	1,050,688 r/	1,019,051 r/	1,061,148 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits, except "Production," and "World, production;" may not add to totals shown.
2/ Direct-shipping ore, concentrates, agglomerates, and byproduct ore.
3/ Excludes byproduct ore.
4/ Transfer and/or receiving docks of Lower Lake ports.
5/ Sum of stocks at mines, consuming plants, and U.S. docks.
6/ Gross weight.

TABLE 2
EMPLOYMENT AT IRON ORE MINES AND BENEFICIATING PLANTS, QUANTITY AND TENOR OF ORE PRODUCED, AND AVERAGE OUT PUT PER WORKER-HOUR IN THE UNITED STATES IN 2000, BY DISTRICT AND STATE 1/

	Average	Worker-	Production (thousand metric tons)				Average per worker-hour (metric tons)		
District and State	number of employees	hours (thousands)	Crude ore	Usable ore	Iron contained in usable ore)	Iron content, natural (percentage)	Crude ore	Usable ore	Iron contained
Lake Superior:									
Michigan 2/	1,700	3,450	45,200	15,000	9,280	61.7	13.12	4.36	2.69
Minnesota	5,100	10,500	162,000	48,000	30,400	63.4	15.43	4.56	2.89
Total or average	6,800	14,000	208,000	63,000	39,700	63	14.86	4.51	2.84
Other States 3/	10	22	55	60	20	34	2.51	2.72	0.92
Grand total or average	6,810	14,000	208,000	63,100	39,700	62.9	14.84	4.51	2.84

See footenotes at end of table.

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TABLE 2--Continued

EMPLOYMENT AT IRON ORE MINES AND BENEFICIATING PLANTS, QUANTITY AND TENOR OF ORE PRODUCED, AND AVERAGE OUT PUT PER WORKER-HOUR IN THE UNITED STATES IN 2000, BY DISTRICT AND STATE 1/

1/ Data are rounded to no more than three significant digits, except "Average per worker-hour," and "Crude ore;" may not add to totals shown.
2/ Does not include professional or clerical workers at mine of plant or maintenance shop nor research lab workers.
3/ Includes California and South Dakota.

TABLE 3

CRUDE IRON ORE MINED IN THE UNITED STATES IN 2000, BY DISTRICT, STATE, AND MINING METHOD 1/ 2/

(Thousand metric tons unless otherwise specified and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Open pit	Underground	Total quantity
Lake Superior:				
Michigan	2	45,200	NA	45,200
Minnesota	8	162,000	NA	162,000
Total	10	208,000	NA	208,000
Other States:	2	55	NA	55
Grand total	12	208,000	NA	208,000

NA Not available.
1/ Excludes byproduct ore.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4

USABLE IRON ORE PRODUCED IN THE UNITED STATES IN 2000, BY DISTRICT, STATE, AND TYPE OF PRODUCT 1/

(Thousand metric tons and exclusive of ore containing 5% or more manganese)

District and State	Direct shipping ore	Concentrates	Agglomerates 2/	Total
Lake Superior:				
Michigan	39	--	15,000	15,000
Minnesota	406	187	47,400	48,000
Total	445	187	62,400	63,000
Other States 3/	55	5	--	60
Grand total	500	191	62,400	63,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Data may include pellet chips and screenings.
3/ Includes California and South Dakota.

TABLE 5

SHIPMENTS OF USABLE IRON ORE FROM MINES IN THE UNITED STATES IN 2000 1/ 2/

(Exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped (thousand metric tons)				Average iron content, natural (percentage)	Value (thousands)
	Direct shipping ore	Concentrates	Agglomerates	Total		
Lake Superior:						
Michigan	43	--	14,200	14,200	61.6	W
Minnesota	299	171	46,300	46,700	63.3	$1,180,000
Total reportable or average	342	171	60,400	60,900	62.9	1,180,000
Other States 3/	109	--	--	109	62.1	2,210
Total withheld	--	--	--	--	--	375,000
Grand total or average	451	171	60,400	61,000	62.9	1,560,000

W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Includes byproduct ore.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes California and South Dakota.

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TABLE 6
CONSUMPTION OF IRON ORE AT U.S. IRON AND STEEL PLANTS 1/ 2/

(Thousand metric tons)

	Iron ore originating areas					
	U.S. ores		Canadian ores			
Year	Great Lakes	Other U.S.	Great Lakes	Other Canada	Foreign ores	Total
1999	56,900 r/	--	448 r/	5,220 r/	5,420 r/	68,000 r/
2000	57,900	--	343	5,920	6,520	70,700

r/ Revised. -- Zero.
1/ Excludes dust, mill scale, and other revert iron-bearing materials added to sinter.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron Ore Association.

TABLE 7
CONSUMPTION OF IRON ORE AT U.S. IRON AND STEEL PLANTS, BY TYPE OF PRODUCT 1/

(Thousand metric tons)

Type of product	1999	2000
Blast furnaces:		
Direct-shipping ore	645	345
Pellets	59,400	61,800
Sinter 2/	10,900	10,600
Total	70,900	72,800
Steelmaking furnaces:		
Direct-shipping ore	48	40
Pellets	24	21
Sinter 2/	172	184
Total	244	245
Grand total	71,200	73,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes briquettes, nodules, and other.

Source: American Iron and Steel Institute.

TABLE 8
U.S. CONSUMPTION OF IRON ORE, BY END USE 1/ 2/

(Thousand metric tons and exclusive of ore containing 5% ore more manganese)

Year	Blast furnaces	Steel furnaces	Sintering plants 3/	Miscellaneous 4/	Subtotal integrated iron and steel plants 5/	Direct-reduced iron for steelmaking 6/	Nonsteel end uses 7/	Total
1999	62,100	57	5,840	2	68,000	2,420	1,290	71,700
2000	64,400	49	6,190	--	70,700	2,340	1,150	74,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes agglomerates.
3/ Excludes dust, mill scale, and other revert iron-bearing materials.
4/ Sold to nonreporting companies or used for purposes not listed.
5/ Data from American Iron Ore Association.
6/ U.S. Geological Survey estimates based on production reports compiled by Midrex Corp.
7/ Includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighing materials, and for use in lead smelting. Data from U.S. Geological Survey surveys.

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TABLE 9
U.S. EXPORTS OF IRON ORE, BY COUNTRY OF DESTINATION 1/ 2/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value	Quantity	Value
Canada	6,100	242,000	6,120	244,000
Other	26	1,460	25	1,890
Total	6,120	243,000	6,150	246,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes agglomerates.

Source: U.S. Census Bureau.

TABLE 10
U.S. EXPORTS OF IRON ORE, BY TYPE OF PRODUCT 1/ 2/

Type of product	1999			2000		
	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 3/ (dollars per metric ton)	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 3/ (dollars per metric ton)
Concentrates	30	912	30.22	51	1,730	34.05
Coarse ores	--	--	--	(4/)	3	102.20
Fine ores	17	565	33.45	25	811	32.93
Pellets	6,050	241,000	39.77	5,870	235,000	39.90
Briquettes	(4/)	11	246.55	(4/)	13	21.62
Other agglomerates	21	795	37.04	201	8,050	40.04
Roasted pyrites	4	269	61.53	3	184	72.55
Total	6,120	243,000	39.72 5/	6,150	246,000	39.95

-- Zero.
1/ Data are rounded to no more than three significant figures, except unit value; may not add to totals shown.
2/ Includes agglomerates.
3/ Unit values shown are calculated from unrounded data.
4/ Less than 1/2 unit.
5/ Weighted average calculated from unrounded data by dividing total value by total tonnage.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS OF IRON ORE, BY COUNTRY AND TYPE OF PRODUCT 1/ 2/

Country and type of product	1999			2000		
	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 3/ (dollars per metric ton)	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 3/ (dollars per metric ton)
Australia	694	8,430	12.14	755	6,180	8.19
Brazil	5,540	138,000	24.82	6,090	150,000	24.68
Canada	6,860	207,000	30.18	7,990	238,000	29.79
Chile	69	1,300	18.83	135	2,620	19.44
Peru	63	918	14.47	40	590	14.75
Sweden	421	13,300	31.64	250	7,930	31.71
Venezuela	327	21,100	64.53	349	11,200	32.15
Other	275	9,320	33.89	78	3,600	46.17
Total	14,300	399,000	28.00	15,700	420,000	26.80
Concentrates	1,440	23,800	16.58	311	6,630	21.32
Coarse ores	318	9,850	31.03	3	104	34.97
Fine ores	3,390	70,800	20.87	5,090	97,100	19.10
Pellets	8,230	264,000	32.03	9,670	302,000	31.23
Briquettes	195	16,900	87.00	--	--	--
Other agglomerates	676	13,700	20.19	611	14,300	23.43
Roasted pyrites	11	561	52.65	6	309	48.60
Total	14,300	399,000	28.00 4/	15,700	420,000	26.80

-- Zero.
1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Includes agglomerates.
3/ Unit values shown are calculated from unrounded data.
4/ Weighted average calculated from unrounded data by dividing total value by total tonnage.

Source: U.S. Census Bureau.

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TABLE 12
U.S. IMPORTS OF IRON ORE IN 2000, BY COUNTRY AND TYPE OF PRODUCT 1/ 2/

(Thousand metric tons)

Country of origin	Concentrates	Coarse ores	Fine ores	Pellets	Other agglomerates 3/	Roasted pyrites	Total
Australia	--	--	755	--	--	--	755
Brazil	--	--	3,940	2,060	95	--	6,090
Canada	128	--	358	7,000	503	--	7,990
Chile	111	--	25	--	--	--	135
Peru	--	--	1	38	--	1	40
Sweden	53	--	--	197	(4/)	--	250
Venezuela	--	--	--	349	--	--	349
Other	20	3	12	25	14	5	79
Total	311	3	5,090	9,670	611	6	15,700

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes agglomerates.
3/ Includes briquettes.
4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 13
AVERAGE UNIT VALUE FOR SELECTED IMPORTS OF IRON ORE IN 2000 1/

Type of product	Country of origin	Average unit value 2/ (dollars per metric ton gross weight)
Concentrates	Canada	17.81
Fine ores	Australia	44.46
Do.	Brazil	21.10
Pellets	do.	30.87
Do.	Canada	31.16

1/ Includes agglomerates.
2/ Weighted averages of individual Customs values.

Source: U.S. Census Bureau.

TABLE 14
U.S. IMPORTS OF IRON ORE, BY CUSTOMS DISTRICT 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
Customs district	Quantity	Value	Quantity	Value
Baltimore	3,210	75,300	4,220	90,400
Charleston	412	13,000	202	6,550
Chicago	2,340	50,200	2,170	47,100
Cleveland	783	21,100	909	26,700
Detroit	1,290	45,100	1,480	47,700
Mobile	2,850	87,100	3,390	108,000
New Orleans	3,170	102,000	3,110	88,600
Philadelphia	84	2,550	114	3,130
Other	124	2,860	84	1,920
Total	14,300	399,000	15,700	420,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes agglomerates.

Source: U.S. Census Bureau.

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TABLE 15
U.S. IMPORTS OF PELLETS, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value	Quantity	Value
Brazil	1,940	60,200	2,060	63,500
Canada	5,780	185,000	7,000	218,000
Peru	--	--	38	526
Sweden	367	11,600	197	6,180
Venezuela	111	3,780	349	11,200
Other	26	2,390	25	2,280
Total	8,230	264,000	9,670	302,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 16
SELECTED PRICES FOR IRON ORE IN THE JAPANESE MARKET

(F.o.b. shipping port basis. U.S. cents per dry long ton of iron)

Country and producer	Ore types	April 1-March 31	
		Fiscal year 1999	Fiscal year 2000
Australia:			
Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd.	Lump ore	34.83	36.84
Do.	Fines	26.63	27.79
Robe River Iron Associates	do.	21.23	22.15
Savage River Mines Ltd.	Pellets	41.99	44.50
Brazil:			
Companhia Nipo-Brasileira de Pelotizacao (Nibrasco)	do.	44.38	47.03
Companhia Vale do Rio Doce (Carajas)	Fines	24.37	25.41
Companhia Vale do Rio Doce (Itabira)	do.	23.87	24.91
Do.	Lump ore	25.95	27.45
Mineraçoes Brasileiras Reunidas S.A.	do.	25.78	27.27
Do.	Fines	24.33	25.39
Samarco Mineracâo S.A.	Pellet feed	20.05	20.92
Canada, Iron Ore Co. of Canada (Carol Lake)	Concentrates	23.15	24.16
Chile:			
Minera del Pacifico S.A. (El Algarrobo)	Pellets	41.35	43.82
Minera del Pacifico S.A. (El Romeral)	Fines	18.49	19.29
India:			
Minerals and Metals Trading Corp. (Bailadila)	Lump ore	33.59	35.53
Do.	Fines	25.56	26.67
Peru, Empresa Minera del Hierro del Peru S.A.	Pellet feed	18.15	18.94
South Africa: 1/			
South African Iron and Steel Industrial Corp. Ltd.	Lump ore	28.50	29.83
Do.	Fines	20.25	21.13

1/ Price per dry metric ton unit.

Source: Trust Fund Project on Iron Ore Information, Iron Ore 2001.

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TABLE 17
IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country 4/	Gross weight 2/					Metal content 3/				
	1996	1997	1998	1999	2000 e/	1996	1997	1998	1999	2000 e/
Algeria	2,245	1,637 e/	1,783 e/	1,336 r/	1,400	1,100	800 e/	900	680 r/	710
Australia	147,100	157,766	155,731 r/	154,268 r/	167,935 5/	93,000	97,901	99,419 r/	95,223 r/	104,226 5/
Austria	1,853	1,800 e/	1,797	1,752	1,800	504	490 e/	500	500	500
Azerbaijan e/	150	NA	NA	NA	NA	83	NA	NA	NA	NA
Bosnia and Herzegovina e/	150	150	150	150	150	50	50	50	50	50
Brazil	174,157	184,970 r/	197,500 r/	194,000 r/	195,000	112,000	122,184	124,210	124,000 r/	125,000
Bulgaria	475	479	462	466	500	320	320 e/	277 e/	280	300
Canada 6/	34,400	37,277	37,808	33,900 r/	35,207 p/	21,911	24,914	24,082	21,967	22,640 p/
Chile	8,324	8,010	8,334 r/	7,632 r/	7,900	5,577 r/	5,367 r/	5,667 r/	5,113 r/	5,293
China e/	249,550	268,000	246,900	237,000 r/	224,000	75,000	80,400	74,500	71,000 r/	67,200
Colombia	600	640	530	580	580	330	350	295	320	320
Egypt	2,429	2,744	3,001	2,700 r/ e/	2,500	1,200 r/	1,400	1,500	1,350 r/	1,250
France e/	1,464 5/	523	250	250	--	430	150	75	35	--
Germany	100	201	200	100 r/	--	15	28	28	14 r/	--
Greece e/ 7/	1,990	NA	NA	1,600	1,500	810	NA	NA	600	575
Guatemala e/	5 5/	3 r/ 5/	4	3	3	3	2 r/	2 r/	2	2
India	66,657	69,453	72,532	70,220 r/	75,000	42,660	44,400	48,000	44,940 r/	48,000
Indonesia e/	425	516	560	563	560	230 e/	280 e/	310 e/	310	310
Iran 8/	9,850	12,750	10,536 r/	10,776 r/	11,000	4,800	6,300	5,200 r/	5,300 r/	5,400
Japan	4	4	2	1	1 5/	2	2	1	1	1 5/
Kazakhstan	13,000	12,600	8,693	9,091	16,160	7,300	7,100	4,900	5,200	9,200
Korea, North e/	11,000	10,000	10,000	7,000 r/	7,000	5,100	4,700	4,700	3,000 r/	3,000
Korea, Republic of	440 r/	500 r/	486 r/	410 r/	336 5/	247 r/	280 r/	272 r/	2,296 r/	188
Macedonia e/	15	15	15	15	15	9	9	9	9	9
Malaysia	325	269 r/	376	337	250	208	172	243	216	158
Mauritania	11,360	11,700	11,400	11,500	11,500	7,384	7,605	7,410	7,475	7,500
Mexico 9/	10,182	10,466	10,557	11,422 r/	11,500	6,109	6,280	6,334	6,853 r/	6,900
Morocco	12	12	9 r/	7 r/	6	8	8 r/	6 r/	4 r/	4
New Zealand 10/	2,334	2,478	2,120 r/	2,303 r/	2,400	700 e/	740 e/	635 r/	720	720
Nigeria e/	100	50	--	--	--	33	17	--	--	--
Norway	1,705	770 r/	637 r/	520 r/	543 r/	1,023	462 r/	382 r/	355 r/	369
Peru	4,364	4,439	4,439	4,230	4,231 p/	2,800	2,850 r/	2,850 r/	2,715 r/	2,688 p/
Portugal 11/	19	18 e/	16	16	15	7	7 e/	7	7	6
Romania e/	670	670	250	200	200	175 5/	170	85	71	70
Russia	72,100	70,900	72,343	81,311	86,630 5/	41,600	40,900	41,700	46,900	50,000
Serbia and Montenegro e/	110	110	100	50	50	34	34	31	15	15
Slovakia	436	453	479	465 r/	450	190	200	215	200	200
South Africa 12/	30,830	33,225	32,948	29,508	33,707 5/	19,115 e/	20,600 e/	20,400	18,442	20,900
Spain 13/	1,269	--	--	--	--	588	--	53	--	--
Sweden	21,020 r/	21,893	20,930	18,558	20,560 5/	13,453 r/	13,912 e/	12,977 r/	11,506	12,747 5/
Thailand	86	44	91	123 r/	100 5/	43 e/	22 e/	46 e/	61 r/	50
Tunisia	239 e/	252 r/	220	219 r/	182 5/	130	137 e/	119 r/	120	98 5/
Turkey	6,404 e/	5,986	5,885	4,300	3,500	3,500 e/	3,239	3,200 e/	2,300 r/	1,900
Ukraine	47,600	53,000 e/	50,758	47,769 r/	55,883 5/	26,200	29,200 e/	28,000	26,200	30,600

See footnotes at end of table.

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TABLE 17--Continued
IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country 4/	Gross weight 2/					Metal content 3/				
	1996	1997	1998	1999	2000 e/	1996	1997	1998	1999	2000 e/
United Kingdom	1	1	1 r/	1 r/	1	1 r/	1 r/ e/	1 r/	1 r/	1
United States	62,083	62,971	62,931	57,749	63,089 5/	39,243	40,022	39,724	36,530	39,703
Venezuela	18,480	18,503	16,553	14,051 r/	17,353 5/	11,520	12,245	11,014	9,292 r/	11,100
Zimbabwe e/	324	479 5/	372 5/	599 r/	451	160	240	190	300 r/	226
Total	1,018,436 r/	1,068,727 r/	1,050,688 r/	1,019,051 r/	1,061,148	546,902 r/	576,489 r/	570,519 r/	552,472 r/	5,801,127

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available. -- Zero.

1/ Table includes data available through July 14, 2001.

2/ Insofar as availability of sources permit, gross weight in this table represent the nonduplicative sum of marketable direct-shipping iron ores, iron ore concentrates, and iron agglomerates produced from imported iron ores have been excluded under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

3/ Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron content reported, except for the following countries for which grades are U.S. Geological Survey estimates: Azerbaijan, Kazakhstan, North Korea, and Ukraine.

4/ In addition to the countries listed, Cuba and Vietnam may also produce iron ore, but definitive information on output levels, if any, is not available.

5/ Reported figure.

6/ Series represented gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.

7/ Nickeliferous iron ore.

8/ Data are for year beginning March 21 of that stated.

9/ Gross weight calculated from reported iron content based on grade of 60% Fe.

10/ Concentrates from titaniferous magnetite beach sands.

11/ Includes manganiferous iron ore.

12/ Includes magnetite ore as follows, in thousand metric tons: 1996--2,070; 1997--2,564; 1998--2,211; 1999--2,200; 2000--2,854.

13/ Includes byproduct ore.

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TABLE 18
IRON ORE: WORLD PELLETIZING CAPACITY, BY CONTINENT AND COUNTRY IN 2000

	Rated capacity (million metric tons, gross weight)
North America:	
Canada	27.6
Mexico	13.7
United States	66.8
Total 1/	108.0
South America:	
Argentina	2.0
Brazil	41.5
Chile	4.4
Peru	6.4
Venezuela	9.9
Total 1/	64.3
Europe:	
Belgium	0.7
Netherlands	4.4
Norway	1.4
Russia	34.0
Sweden	16.4
Turkey	1.0
Ukraine	32.0
Total 1/	89.9
Africa:	
Liberia	3.0
South Africa	0.6
Total 1/	3.6
Asia:	
Bahrain	4.0
China	20.0
India	8.5
Iran	9.0
Japan	3.0
Kazakhstan	8.4
Total 1/	52.9
Oceania, Australia	4.0
Grand total 1/	323.0

1/ Data may not add to totals shown because of independent rounding.

Sources: International Iron and Steel Instuitute, Brussels, Belgium; United Commission on Trade and Development; Trust Fund on Iron Ore Information; U.S. Geological Survey.

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IRON OXIDE PIGMENTS

By Michael J. Potter

Domestic survey data and tables were prepared by Richelle J. Ellis, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Natural iron oxides are derived from hematite, which is a red iron oxide mineral; limonites, which vary from yellow to brown, such as ochers, siennas, and umbers; and magnetite, which is black iron oxide. Synthetic iron oxide pigments are produced from basic chemicals. The three major methods for the manufacture of synthetic iron oxides are thermal decomposition of iron salts or iron compounds, precipitation of iron salts usually accompanied by oxidation, and reduction of organic compounds by iron (Podolsky and Keller, 1994, p. 765, 772).

Production

U.S. output of finished natural (mined) iron oxide pigments (IOPs) sold by processors in 2000 was 87,800 metric tons (t), about 5% less than in 1999; this category accounted for 51% of the tonnage and 15% of the value of total IOP output. Finished synthetic IOPs were 83,900 t, a decrease of 8% from that of 1999, and accounted for 49% of the tonnage and 85% of the value of total IOP output. Total finished natural and synthetic IOPs were 172,000 t, about 6% less than in 1999 (table 2).

Production data for crude IOPs sold or used were developed from a voluntary survey. Of six known companies, data were obtained from five, for an 83% response rate. By tonnage, the five companies represented about 70% of the output. In a second voluntary survey, data were received from 12 of 14 known operations that produced finished IOPs, for a response rate of 86%. By tonnage, the 12 operations represented 80% of the output.

Data were obtained from three producers of regenerator iron oxide, which is obtained when spent pickle liquor from steelmaking is treated (table 3). Output from the three companies was about 34,500 t of iron oxide. A major end use for this material was ferrites. Regenerator iron oxide data are not included in tables 1, 2, and 4.

Bayer Corp. introduced two new yellow grades of synthetic IOPs, which were geared toward use in standard solvent-based paints and coatings, as well as high solids and water-based paints. One of the pigments was being manufactured at the company's new iron oxide unit at New Martinsville, WV, and the other yellow pigment was being made at Bayer's facility near Sao Paulo, Brazil, specifically for sale in North American markets (Bayer Corp., October 23, 2000, Bayer Corp. introduces two new yellow grades of synthetic iron oxide pigments for use in architectural paints and coatings, accessed June 21, 2001, at URL http://www.bayerus.com/new/2000/10.23.00.html).

Laporte plc announced its intention to sell its pigments and additives companies to K-L Holdings Inc., a company established by Kohlberg Kravis Roberts & Co., L.P. Laporte's Pigments Division comprised IOP companies in the United States and Europe. Markets included construction, coatings, and specialty applications (Industrial Minerals, 2000).

Consumption

The largest end-use categories for total U.S. IOP output (natural and synthetic) in 2000 continued to be construction with 32% and coatings with 22% (table 4).

In New Jersey, a noise barrier concrete wall was installed along a 26-kilometer corridor on interstate highways. Coloring for the entire wall system was a brownish gray (taupe) supplied by Bayer Corp. and was similar to the color of tree trunks surrounding the noise barrier. Changes in reflective light and the varying textures of the wall gave the appearance of three different colors being used (Bayer Corp., May 9, 2000, Color concrete noise barrier walls enhance landscapes along U.S.

Iron Oxide Pigments in the 20th Century

In 1900, U.S. output of natural (mined) iron oxide pigments (IOPs), including ocher, sienna, umber, and "metallic paint" was about 39,000 metric tons with a value of $490,000. "Metallic paint" was red and brown iron oxides produced by grinding the impure mineral in the natural state. Imports of ocher, sienna, and umber were about 5,000 tons. Other major producing countries of ocher were France with 33,100 tons, the United Kingdom with 15,400 tons, and the German Empire with 11,500 tons. In the early 1900s in the United States, natural IOPs were used mostly in linoleum and ready-mixed paints. The other category of IOPs, synthetic, is made by a chemical process, such as the Penniman-Zoph precipitation process, which became commercially important around the 1930s. During World War II, many IOP producers geared their operations more closely to war needs such as olive drab and camouflage paints for military vehicles, artillery, and aircraft. Paint for shipbuilding required large quantities of both natural and synthetic red iron oxide. After the war ended, peace time uses resumed, such as farm buildings, box cars, and domestic construction.

In 2000, total U.S. output of finished IOPs (natural and synthetic) was 172,000 tons with a value of $171 million. The largest end-use categories for total IOP output were construction (such as cement, mortar, and concrete) and paints and coatings. Total U.S. imports of IOPs (natural and synthetic) were 91,300 tons, with China supplying about 48,000 tons, or 53 %, most of which was synthetic material.

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interstates, accessed June 21, 2001, at URL http://www.bayerus.com/new/2000/05.10.00html).

Concrete roof tile has made a major appearance throughout the United States during the past 15 to 20 years. Concrete tile roofs initially were found only in the sunbelt areas of Arizona, California, southern Florida, and Nevada because of the strong Spanish and Mediterranean influences. Newer styles have been developed, along with improved installation procedures, and concrete roof tiles have spread to colder areas, including Colorado, Minnesota, Montana, and Utah. Styles available from at least one supplier include flat tile that simulates wood shakes or shingles and smooth slate. Color for the tiles is from numerous shades of black, red, and yellow IOPs. Two or more of these shades are blended to create a wide selection of earth-tone colors, including shades of adobe, buff, and tan. Concrete roof tile strengthens over time; in Europe, where concrete roof tile has been the predominant roofing material for nearly a century, roof tiles can last over 75 years, even in severe weather conditions. The tiles are also fire resistant, and technological advances have enabled the tile to rival the appearance of clay tile (Bayer Corp., October 17, 2000, Colorful concrete roof tile enhances the quality and style of homes throughout the United States, accessed June 21, 2001, at URL http://www.bayerus.com/new/2000/10.17.00.html).

IOPs, especially those with large particle size that maximizes opacity and gives high color strength, have been manufactured since the late 19th century. In the past 40 years, synthetically produced transparent iron oxides have been developed that give and enhance color and protect wood against weathering, fungi, and ultraviolet radiation. The preferred processes for the manufacture of transparent iron oxide involve precipitation and oxidation of iron from a ferrous salt solution. Ferrous sulfate is the preferred salt because it is readily available as a byproduct from the manufacture of titanium dioxide pigment or from the steel pickling industry. In wood stains and furniture finishes, transparent IOPs find applications such as fencing, decks, lawn furniture, siding, cabinetry, and flooring (Wright and McKenna, 2000).

Prices

Yearend 2000 prices, meant to serve as a general guideline, converted to dollars per kilogram, in bags, per truckload, free on board (f.o.b.) warehouse, were synthetic black, $1.85 to $1.96; synthetic brown, $1.83 to $1.94; natural red, $0.65 to $1.10; natural ochre, $0.81; and synthetic yellow, $1.80 to $1.94 (Chemical Market Reporter, 2000). These prices were essentially unchanged from those of 1999.

The average annual Producer Price Index (PPI) for IOPs for 2000 was 174.9, compared with 173.0 in 1999. The PPI measures the average change over time in the selling prices received by domestic producers of IOPs. The base year for the IOP PPI is June 1983 (Bureau of Labor Statistics, June 20, 2001, Producer price index revision—Current series, accessed June 28, 2001, at URL http://stats.bls.gov/sahome.html).

Foreign Trade

U.S. exports of pigment grade IOPs in 2000 were 9,640 t, 30% less than those of 1999 (table 5). The largest recipients were Japan (22%), Mexico (22%), and Germany (15%).

In 2000, U.S. imports of natural IOPs were 7,340 t (tables 6, 7). The 718 t of micaceous iron oxide (MIO) from Belgium and 913 t from the Netherlands in 2000, however, may not belong in this table, because those countries are not known to be suppliers of MIO. This has yet to be verified with the U.S. Census Bureau; if verified, U.S. imports of MIO would drop to 588 t with a value of $463,000. Imports of synthetic IOPs were 84,000 t, 8% higher than those of 1999. The largest amounts of material were supplied by China (57%), Germany (19%), and India (5%). The total value of synthetic IOPs imports was $73.3 million, which was an increase of 6% compared with imports in 1999.

Total U.S. imports of IOPs (natural and synthetic) were 91,300 t, 7% more than in 1999. The total value of the imports was $76.7 million, 5% higher than that of 1999 (tables 6, 7).

Outlook

Consumption of IOPs is related to activity in the automotive, construction, and housing industries. U.S. apparent consumption of IOPs in 2000 (calculated as production plus imports minus exports) was about 254,000 t, about the same as in 1999. Although housing starts in 2000 were estimated to be about 4% fewer than in 1999, growth in IOP demand reportedly has exceeded overall construction market growth because of an increasing preference for concrete products. An example is the roof tile segment of the industry. One area of the paint industry that has shown above average growth is that of architectural coatings. Use of IOPs as a colorant in plastics reportedly has been spurred in part by plastics continually replacing metal and glass in products such as automobiles (Chemical Products Synopsis, 2000).

References Cited

Chemical Market Reporter, 2000, Chemical prices: Chemical Market Reporter, v. 258, no. 25, December 18, p. 22-29.

Chemical Products Synopsis, 2000, Iron oxide: Adams, NY, Mannsville Chemical Products Corp., September, 2 p.

Industrial Minerals, 2000, World of minerals: Industrial Minerals, no. 398, November, p. 21-23.

Podolsky, George, and Keller, D.P., 1994, Pigments—Iron oxide, *in* Carr, D.D., and others, eds., Industrial minerals and rocks, 6th ed.: Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., p. 765-781.

Wright, Peter, and McKenna, M.F., 2000, Using transparent iron oxide pigments in wood finish applications: Paint & Coatings Industry, v. 16, no. 11, November, p. 44-54.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publication

Pigments and Fillers. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Intertech conferences, Portland, ME.

Iron Oxide Pigments—Pt. 1—Fine-particle Iron Oxides for Pigment, Electronic, and Chemical Use. U.S. Bureau of Mines Information Circular 8771, 1978.

Iron Oxide Pigments—Pt. 2—Natural Iron Oxide Pigments—Location, Production, and Geological Description. U.S. Bureau of Mines Information Circular 8813, 1980.

Pigment Handbook (2d ed.), John Wiley & Sons, 1988.

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TABLE 1
SALIENT U.S. IRON OXIDE PIGMENTS STATISTICS 1/

(Metric tons, unless otherwise noted)

		1996	1997	1998	1999	2000
Crude pigments sold or used 2/		44,700	46,900	46,100	44,100	57,100
Value	thousands	$6,990	$7,580	$7,290	$7,740	$4,470
Finished pigments sold 3/		163,000	176,000	180,000	183,000 r/	172,000
Value	thousands	$183,000	$193,000	$193,000	$187,000 r/	$171,000
Exports		16,000	16,600	14,600	13,800	9,640
Value	thousands	$23,200	$20,600	$18,200	$15,200	$17,200
Imports for consumption		59,600	68,200	67,500	85,100	91,300
Value	thousands	$72,800	$75,400	$64,200	$73,000	$76,700

r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Mined.

3/ Natural (mined) and synthetic.

TABLE 2
FINISHED IRON OXIDE PIGMENTS SOLD BY PROCESSORS IN THE UNITED STATES, BY KIND 1/

	1999		2000	
Kind	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Natural:				
Black; magnetite	21,000	$3,690	19,400	$3,190
Umbers:				
Burnt	2,440	3,280	2,100	2,880
Raw	W	W	W	W
Red, iron oxide 2/	55,700	11,800	52,700	10,600
Undistributed and other 3/	12,900	8,590	13,600	8,550
Total	92,000	27,300	87,800	25,200
Synthetic:				
Black, iron oxide	24,700 r/	40,600 r/	22,400	35,800
Brown, iron oxide	(4/) r/	(4/) r/	7,570	13,800
Red, iron oxide	(4/) r/	(4/) r/	53,900	95,800
Yellow, iron oxide	22,700 r/	40,300 r/	(5/)	(5/)
Mixtures of natural and synthetic; iron oxides	(4/) r/	(4/) r/	(6/)	(6/)
Other; specialty oxides	(4/) r/	(4/) r/	--	--
Undistributed	43,800 r/ 7/	79,200 r/ 7/	--	--
Total	91,200 r/	160,000 r/	83,900	145,000
Grand total	183,000 r/	187,000 r/	172,000	171,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Undistributed and other." -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes pyrite cinder.

3/ Includes raw umber, burnt sienna, ochre and raw sienna.

4/ Included with "Undistributed" to avoid disclosing company proprietary data.

5/ Included with "Red, iron oxide" to avoid disclosing company proprietary data.

6/ Included with "Brown, iron oxide" to avoid disclosing company proprietary data.

7/ Includes brown iron oxide, red iron oxide, mixtures of natural and synthetic iron oxide and other specialty oxides.

TABLE 3
PRODUCERS OF IRON OXIDE PIGMENTS, REGENERATOR IRON OXIDES,
AND STEEL PLANT WASTE IRON OXIDES IN THE UNITED STATES IN 2000

Producers	Plant location
Finished pigments:	
Alabama Pigments Co.	Green Pond, AL.
Arizona Oxides L.L.C.	El Mirage, AZ.
Bayer Corp.	New Martinsville, WV.
Dynamic Color Solutions, Inc.	Milwaukee, WI.
Elementis Pigments Inc.	Emeryville, CA; East St. Louis, IL; Easton, PA.
Hoover Color Corp.	Hiwassee, VA.

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TABLE 3--Continued
PRODUCERS OF IRON OXIDE PIGMENTS, REGENERATOR IRON OXIDES,
AND STEEL PLANT WASTE IRON OXIDES IN THE UNITED STATES IN 2000

Producers	Plant location
Finished pigments--Continued:	
Hoover Color Corp.	Hiwassee, VA.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Pea Ridge Iron Ore Co.	Sullivan, MO.
Prince Manufacturing Co., Inc.	Quincy, IL and Bowmanstown, PA.
Rockwood Pigments Inc.	Beltsville, MD and St. Louis, MO.
Solomon Grind-Chem Services Inc.	Springfield, IL.
Crude pigments:	
Alabama Pigments Co.	Green Pond, AL.
Arizona Oxides L.L.C.	El Mirage, AZ.
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer plant (closed July 31, 1979; shipping from stockpile.)	Negaunee, MI.
Hoover Color Corp.	Hiwassee, VA.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Pea Ridge Iron Ore Co.	Sullivan, MO.
Regenerator and steel plant waste iron oxides:	
Bailey-PVS Oxides, L.L.C.	Fairfield, AL.
International Steel Services, Inc.	Allenport, PA.
Weirton Steel Corp.	Weirton, WV.

TABLE 4
ESTIMATED IRON OXIDE PIGMENT CONSUMPTION, BY END USE, AS A PERCENTAGE OF REPORTED SHIPMENTS

	All iron oxides		Natural iron oxides		Synthetic iron oxides	
End use	1999 r/	2000	1999	2000	1999	2000
Coatings (industrial finishes and trade sales coatings: lacquers, paints, varnishes)	22	22	15	12	29 r/	31
Construction materials (cement, mortar, preformed concrete, roofing granules)	30	32	20	23	W	W
Colorants for ceramics, glass, paper, plastics, rubber, textiles	10	10	W	W	11	10
Foundry sands	8	W	15	W	--	--
Industrial chemicals (such as catalysts)	8	8	W	W	W	W
Other 1/	22	28	50 r/	65	60 r/	59
Total	100	100	100	100	100	100

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Includes animal feed, cosmetics, ferrites, fertilizers, magnetic ink and toner, polishing agents and data indicated by the symbol W.

TABLE 5
U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY 1/

	1999				2000			
	Pigment grade		Other grade		Pigment grade		Other grade	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	68	$279	106	$57	4	$14	79	$21
Australia	90	204	297	703	153	301	305	732
Belgium	86	672	90	417	5	29	33	128
Brazil	17	54	248	603	48	28	255	465
Canada	41	51	11,000	13,500	38	42	10,600	12,100
China	223	798	39	88	84	156	452	143
Colombia	33	57	63	69	51	205	89	103
France	35	81	278	1,450	9	29	210	679
Germany	976	1,430	767	4,840	1,450	1,920	2,280	4,510
Hong Kong	11	30	1,600	4,780	529	288	1,310	3,290
India	476	759	314	387	281	382	491	622
Indonesia	10	31	167	246	15	32	219	291
Italy	18	51	144	367	--	--	909	808

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY 1/

	1999				2000			
	Pigment grade		Other grade		Pigment grade		Other grade	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Japan	1,710	$2,200	3,690	$9,360	2,160	$3,860	3,610	$7,160
Korea, Republic of	327	484	2,860	10,500	467	727	1,210	3,480
Malaysia	--	--	27	22	--	--	338	1,060
Mexico	7,740	3,450	3,210	3,740	2,100	2,060	2,560	2,340
Netherlands	146	394	897	1,440	--	--	792	1,290
Russia	105	370	20	80	508	755	16	44
Singapore	16	41	118	228	38	224	160	294
South Africa	294	401	1	5	1	3	3	5
Taiwan	60	113	1,120	908	204	1,070	1,340	1,320
Thailand	41	141	500	2,130	127	121	292	266
Turkey	--	--	19	51	3	16	--	--
United Kingdom	821	2,400	2,080	3,150	1,150	4,520	2,800	4,620
Venezuela	13	45	23	134	3	13	105	35
Other	423	665	378	639	221	421	435	758
Total	13,800	15,200	30,100	59,800	9,640	17,200	30,900	46,500

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF SELECTED IRON OXIDE PIGMENTS, BY TYPE 1/

	1999		2000		
Type	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Principal sources, 2000 (metric tons)
Natural:					
Earth colors 3/	4,680	$2,020	5,120	$2,240	Cyprus, 3,850; Spain, 781; Germany, 345; India, 125; South Africa, 21; United Kingdom, 3; Italy, 1; Japan, (4/).
Micaceous	2,770	1,690	2,220	1,170	Netherlands, 913; Belgium, 718; Australia, 196; Austria, 151; France, 91; China, 80; Morocco, 48; Mexico, 20; Italy, 2; Germany, (4/).
Total	7,450	3,710	7,340	3,410	
Synthetic:					
Black	12,000	15,800	16,000	22,500	China, 4,580; India, 4,160; Germany, 3,920; Japan, 892; Mexico, 829; Italy, 744; Hong Kong, 376; Netherlands, 230; United Kingdom, 110; Canada, 84; Belgium, 45.
Red	35,000	25,700	36,300	25,500	China, 23,900; Germany, 6,570; Canada, 1,540; Hong Kong, 862; Netherlands, 708; Italy, 520; Mexico, 471; India, 339; Spain, 335; Japan, 273; United Kingdom, 261; Brazil, 152; Colombia, 114; New Caledonia, 100; Sweden, 72; Czech Republic, 36; France, 32; Belgium, 1.
Yellow	28,600	24,700	30,000	22,600	China, 19,400; Germany, 4,640; Brazil, 2,870; Mexico, 1,470; Hong Kong, 612; Italy, 398; Spain, 141; United Kingdom, 130; Canada, 121; Colombia, 58; Ukraine, 41; Belgium, 36; Hungary, 34; Japan, 21; France, 19; Republic of Korea, 17; Switzerland, 1.
Other 5/	1,960	3,110	1,780	2,630	Germany, 1,030; Canada, 470; China, 181; Mexico, 24; Italy, 20; India, 20; Poland, 19; United Kingdom, 7; Belgium, 3; Japan, 3.
Total	77,600	69,300	84,000	73,300	
Grand total	85,100	73,000	91,300	76,700	

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Customs value.

3/ Includes those earth colors not elsewhere specified or included.

4/ Less than 1/2 unit.

5/ Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF IRON OXIDE AND IRON HYDROXIDE PIGMENTS, BY COUNTRY 1/

	Natural				Synthetic			
	1999		2000		1999		2000	
Country	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Austria	227	$249	151	$146	--	--	--	--
Belgium	--	--	718	303	49	$321	86	$396
Brazil	--	--	--	--	2,270	2,170	3,020	2,890
Canada	18	3	--	--	4,060	1,960	2,210	1,750
China	20	18	80	36	40,000	21,700	48,000	25,500
Colombia	67	112	--	--	124	155	172	228
Cyprus	3,820	1,280	3,850	1,510	--	--	--	--
France	292	225	91	73	74	711	51	516
Germany	278	364	345	474	17,200	22,800	16,100	18,700
Hong Kong	--	--	--	--	586	370	1,850	1,320
India	147	34	125	29	3,330	2,240	4,520	3,180
Italy	--	--	2	12	2,810	2,920	1,680	2,030
Japan	(3/)	2	(3/)	3	1,450	7,670	1,190	11,200
Mexico	21	4	20	3	2,540	2,290	2,790	2,470
Netherlands	2,220	1,190	913	407	173	87	938	346
Spain	160	59	781	180	530	437	476	304
Sweden	--	--	--	--	1,150	307	72	22
United Kingdom	(3/)	6	3	22	1,010	2,880	509	2,160
Other	189	159	265	217	197	299	247	252
Total	7,450	3,710	7,340	3,410	77,600	69,300	84,000	73,300

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
NATURAL IRON OXIDE PIGMENTS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Austria e/	7,500	7,500	7,000	7,000	7,000
Brazil e/	5,500	5,500	5,500	5,500	5,500
Chile	18,821	10,678	10,449	10,500 e/	10,600
Cyprus (umber)	4,604	7,120 r/	6,056 r/	9,169 r/	12,258 4/
France e/	1,000	1,000	1,000	1,000	1,000
Germany 5/	3,754	4,176	4,000 e/	4,000 e/	4,000
India (ocher)	284,546	347,429	351,704	360,000 e/	365,000 4/
Iran	2,500 e/	10,000 r/	13,300 r/	13,300 r/	13,500 4/
Italy e/	500	500	500	500	500
Pakistan (ocher) e/	6,100	2,600	3,180 4/	3,200	4,700
Paraguay (ocher) e/	300	300	300	300	300
South Africa	643	284	186	216	569 4/
Spain: e/					
Ocher	7,000	7,000	7,000	7,000	7,000
Red iron oxide	15,000	15,000	15,000	15,000	15,000
United States	44,700 r/	46,900 r/	46,100 r/	44,100 r/	57,100 4/
Zimbabwe e/	400	--	--	--	--

e/ Estimated. r/ Revised. -- Zero.
1/ Estimated data are rounded to no more than three significant digits.
2/ Table includes data available through June 4, 2001.
3/ In addition to the countries listed, a number of others undoubtedly produce iron oxide pigments, but output is not reported and no basis is available for formulating estimates of output levels. Such countries include, but are not limited to, Azerbaijan, China, Kazakhstan, Russia, and Ukraine. Unreported output is probably substantial.
4/ Reported figure.
5/ Includes Vandyke brown.

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KYANITE AND RELATED MATERIALS

By Michael J. Potter

Domestic survey data and tables were prepared by John G. Durand, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Kyanite, andalusite, and sillimanite are anhydrous aluminosilicate minerals with the same chemical formula (Al_2SiO_5) but different crystal structures and physical properties. When calcined at high temperatures (in the 1,400° C to 1,500° C range for kyanite and andalusite and 1,550° C to 1,625° C for sillimanite), these minerals are converted to mullite (Al_6SiO_{13}) and silica (SiO_2) (Harben, 1999). Mullite is a refractory material. During calcination, 1 metric ton (t) of aluminosilicate concentrate yields about 0.88 t of mullite. Synthetic mullite is made by heating mixtures of bauxite and kaolin or alumina and silica at about 1,550° C to 2,000° C (Roskill Information Services Ltd., 1990).

In 2000, the United States, at an estimated 90,000 t, continued to be the main producer of kyanite; reported production data are withheld to avoid revealing company proprietary information. South Africa continued as the leading producing country of andalusite, with over 185,000 t. Sillimanite has had limited production; India has supplied most of the world's output with about 12,000 metric tons per year (t/yr) in recent years.

Legislation and Government Programs

The defense national stockpile contained a total of 136 t of kyanite at yearend 2000. This material was being offered for sale on the third Thursday of every month (Defense National Stockpile Center, November 13, 2000, Kyanite, accessed March 13, 2001, at URL http://www.dnsc.dla.mil/kyanite.htm).

Production

Kyanite Mining Corp. operated two open pit mines in Buckingham County, VA, and beneficiated the ore into marketable kyanite. Some of the kyanite was calcined for conversion into mullite. Company data are proprietary, but Dickson (2000) has estimated U.S. output to be about 90,000 t/yr valued at approximately $13.4 million (before any material was converted to mullite), using a value of $149 per metric ton, the lowest value listed in table 1. High-temperature sintered synthetic mullite, made from calcined bauxitic kaolin and known as one of the company's Mulcoa products, was produced by C-E Minerals, Inc., near Americus, GA. Estimated U.S. production was about 40,000 t/yr (Dickson, 2000) valued at approximately $9.7 million, using a value of about $243 per ton. Kyanite prices, both raw and calcined, increased by about 5% early in 2000 (table 1); Mulcoa prices increased by about 4% in the first half of 1999, but there had been no further increases since then (Dickson, 2000).

Piedmont Minerals Co., Inc., in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sells products containing blends of the three minerals to refractories and ceramics producers. There was no known U.S. output of sillimanite.

Consumption

Refractories are the largest end use of kyanite, andalusite,

Kyanite and Related Materials in the 20th Century

Kyanite and related materials were not surveyed by the U.S. Geological Survey until 1939 and probably were not mined at the beginning of the 20th century. Test work on spark plug porcelain at the National Bureau of Standards during World War I stimulated a search for natural sources of these minerals. Andalusite was mined in California and in Nevada for spark plug insulators for the automobile industry. Andalusite mined in California from 1922 to 1936 amounted to about 18,000 metric tons. Kyanite was mined at various periods between 1925 and 1986 in California, Georgia, North Carolina, and South Carolina. In 1932, refractory uses of kyanite included boiler furnaces, brass-melting furnaces, cement kiln linings, electric furnaces, and forging furnaces. The largest long-term kyanite output had come from Virginia from around 1940 and continued into 2000. India was a major producer of kyanite, with output ranging from about 16,000 tons in 1946 to about 119,000 tons in 1970. Production then gradually decreased to the 5,000- to 10,000-ton range in the 1990s. Kyanite was mined in Kenya from about 1946 to 1955, reaching a peak production of about 23,600 tons in 1949. Reserves of easily mined massive kyanite boulders were exhausted in 1952.

In 2000, the United States was the leading producer of kyanite, with an estimated 90,000 tons. South Africa, the leading producer of andalusite, had initial production at least as early as 1939, which then generally increased over time, reaching a high of 284,000 tons in 1989. France was the other significant producer of andalusite; activity began in the early 1970s, and annual output in the late 1990s and 2000 was about 65,000 tons. High-temperature refractories had been and continued to be the largest end use of kyanite, andalusite, and sillimanite. The steel industry used an estimated 60% of refractories in general. Other applications for these heat-resistant materials are in high-temperature environments in furnaces, boilers, ladles, and kilns in the metallurgical, glass, chemical, cement, and other industries.

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mullite, and synthetic mullite in the United States and worldwide. Mullite in refractories increases the fired strength, resistance to deformation under load, and thermal resistivity. Examples include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure), including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. The interlocking grain structure of kyanite/mullite also gives much added mechanical strength to other ceramic compositions even when fired at low temperatures during manufacture. This has resulted in increased use of kyanite in sanitaryware, wall tile, precision casting molds, electrical porcelain, and other products.

Sillimanite was not known to be used in the United States in 2000.

Foreign Trade

The United States exported kyanite, mullite, and synthetic mullite to countries in Europe, Latin America, and the Pacific rim. Although the U.S. tariff code does not differentiate between kyanite, andalusite, and sillimanite, 6,230 t out of 6,440 t of total imports in 2000 were from South Africa and were presumed to be andalusite (table 2). There were no known U.S. imports of kyanite or sillimanite in 2000.

World Review

India.—Mining and mineral processing company Bajaj Associates reportedly began producing sintered mullite for use in the refractories industry. The plant, located at Bangalore, had a capacity of 10,000 t/yr. Raw kyanite feedstock, with 35% to 52% alumina, was being mined about 200 kilometers south of Bangalore. The plant was using Bajaj's own technology, including crushing, grinding, and briquetting equipment, and a rotary kiln. Output was around 800 metric tons per month (t/mo) of kyanite fines and 200 t/mo of sintered mullite for local refractory manufacturers (Industrial Minerals, 2000a).

Japan.—The Japanese refractories industry is known to be very technically advanced but was facing some difficult challenges. Production levels of refractories worldwide have fallen; refractory output tonnage in Japan is less than one half that of the mid-1970s. There has been substantial consolidation and restructuring of refractories companies in Europe and the United States in recent years. By contrast, there were still some 66 refractory manufacturers and 89 manufacturing plants in Japan in 1998. Approximately 70% of refractory demand comes from the steel industry, and many refractory producers are partly or fully owned by steel manufacturers and cement companies. There also has been a rise in imports of low-priced refractory finished products, especially from China (Pearson, 2000).

Because of a lack of indigenous mineral resources, most of Japan's refractory raw material supply was imported. With increasingly stringent requirements concerning purity and properties of refractory materials, refractory manufacturers in Japan and worldwide have turned to synthetic minerals, fused minerals in particular. Naigai Ceramics Co., Ltd., was producing 1,000 t/mo of fused mullite, mainly for hot-blast stove refractories (Pearson, 2000).

Turkey.—The Turkish refractories producer Haznedar Ateş Tuğla Sanayii AŞ was to begin production at a new refractories plant in Istanbul. The targeted production level was 50,000 to 60,000 t/yr of high density alumina and magnesia bricks. Raw materials included calcined bauxite, andalusite, and tabular alumina (a well-sintered, high purity, coarse crystalline alpha alumina; the tabular name comes from its hexagonal tablet-shaped crystal composition) (Alcoa World Chemicals, [undated], Products, accessed April 2, 2001, via URL http://www.alumina.alcoa.com/products). Sources of imported raw materials were both local and foreign. About 70% to 75% of the refractories were for local use and the reminder for export (Industrial Minerals, 2000b).

United Kingdom.—Keith Ceramic Materials, Ltd. (KCM), a major producer of fused mullite, was acquired by the Treibacher Schleifmittel AG subsidiary of the French Imerys Group. Treibacher, the world's leading producer of fused alumina, was acquired by Imerys in the first half of 2000. KCM was producing white fused mullite and fused zirconia mullite for use in glass and steel refractories mostly for the European market (Industrial Minerals, 2000c).

Outlook

The largest user of refractories in general in the United States continued to be the iron and steel industry. Raw steel output was about 3% higher than in 1999, according to preliminary data (American Iron and Steel Institute, February 7, 2001, December steel shipments down 17.5% from previous year import surge overshadows 2000 shipment gain, accessed March 8, 2001, at URL http://www.steel.org/news/pr/2001/pr010207_imp.htm). In the steel industry, ladle linings have continued to evolve. Ladle metallurgy has seen increasingly severe operating conditions, such as higher temperature, more chemical attack, and longer exposure time. Brick linings are still dominant in the United States, but the use of monolithics is increasing (Semler, 2000). Advances in steelmaking and other manufacturing processes have resulted in less intensive use of refractories per unit of output produced. Refractories suppliers have been developing products with superior performance and increased longevity, which require less frequent replacement and maintenance. According to Freedonia Group, Inc., opportunity for more growth for refractory products may exist in the petroleum and chemicals market. Of the major refractory forms, monolithic castables and preformed shapes are projected to be the best growth prospects (Ceramic Industry, 2000).

References Cited

Ceramic Industry, 2000, U.S. demand for refractories to reach $2.8 billion through 2003: Ceramic Industry, v. 150, no. 9, August, p. 45-46.

Dickson, Ted, 2000, Sillimanite minerals, Industrial Minerals Annual Review Supplement: Mining Journal [London], CD ROM, 3 p.

Harben, P.W., 1999, Sillimanite minerals *in* The industrial minerals handybook III: Surrey, UK, Industrial Minerals Information Ltd., p. 191-193.

Industrial Minerals, 2000a, Bajaj Associates sets up sintered mullite plant: Industrial Minerals, no. 389, February, p. 11.

———2000b, Haznedar expands with new refractories plant: Industrial Minerals, no. 398, November, p. 16.

———2000c, Imerys completes alumina portfolio with Keith Ceramics purchase: Industrial Minerals, no. 396, September, p. 8.

Pearson, Karine, 2000, The Chinese invasion—A survival guide to Japan's refractories industry: Industrial Minerals, no. 389, February, p. 28-37.

Roskill Information Services Ltd., 1990, The economics of kyanite 1990: London, Roskill Information Services, Ltd., 118 p. plus appendices.

Semler, C.E., 2000, Refractories update a la Aruba—A review of ALAFAR '99: Ceramic Industry, v. 150, no. 2, February, p. 44-50.

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Kyanite and Related Minerals. Ch. in Mineral Commodity Summaries, annual.
Kyanite and Related Minerals. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Kyanite and Related Minerals. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Sillimanite Group—Kyanite and Related Minerals. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, 6th ed., Donald Carr, ed., 1994.

TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS IN 2000

(Dollars per metric ton)

	Price
Andalusite, South Africa, 57% alumina, 2,000-metric-ton bulk, f.o.b. 1/	161
Andalusite, South Africa, 58% alumina, 2,000-metric-ton bulk, f.o.b. 1/	189
Kyanite, USA (VA), 54% to 60% alumina, 35-325 mesh, 18-ton lots:	
Raw	149-182
Calcined	262-295

1/ Free on board.

Source: Industrial Minerals, no. 399, December 2000, p. 75.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE 1/ 2/ 3/

Year	Quantity (metric tons)	Value 4/ (thousands)
1999	6,290	$1,330
2000	6,440	1,320

1/ Most material is from South Africa.
2/ Harmonized Tariff System (HTS) code: 2508.50.0000.
3/ Data are rounded to no more than three significant digits.
4/ Customs value.

Source: U.S. Census Bureau.

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TABLE 3
KYANITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country and commodity 3/	1996	1997	1998	1999	2000
Australia:					
Kyanite	800	800	800	1,000	1,000
Sillimanite 4/	100	100	100	100	100
Brazil, kyanite	600	600	600	600	600
China, unspecified	2,500	3,000	3,050	3,000	3,000
France, andalusite	70,000	67,000	65,000	65,000	65,000
India:					
Kyanite	6,715 5/	6,035 5/	5,169 5/	5,000	5,000
Sillimanite	7,521 5/	12,299 5/	11,936 5/	12,000	12,000
Kenya, kyanite	(6/)	--	--	--	--
South Africa:					
Andalusite	233,728 5/	251,203 5/	236,200 5/	136,900 r/ 5/	185,055 5/
Sillimanite	-- 5/	-- 5/	65 5/	--	--
Spain, andalusite	3,500	3,500	3,000	2,500	2,500
United States:					
Kyanite	W	W	90,000	90,000	90,000
Mullite, synthetic	W	W	39,000	39,000	40,000
Zimbabwe	141 5/	1,113 5/	3,780 5/	4,000	4,000

r/ Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

1/ U.S. and estimated data are rounded to no more than three significant digits.

2/ Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 20, 2001.

3/ In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

4/ In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al_2O_3.

5/ Reported figure.

6/ Less than 1/2 unit.

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LEAD

By Gerald R. Smith

Domestic survey data and tables were prepared by Richelle J. Ellis, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

Domestic lead mine production decreased by about 9% compared with that of 1999. Alaska and Missouri were the dominant producing States with a 91% share. Other appreciable lead mine production was in Idaho and Montana. Lead was produced at 19 mines employing about 1,100 people. The value of domestic mine production was about $440 million. The lead concentrates produced from the mined ore were processed into primary metal at two smelter-refineries in Missouri and a smelter in Montana.

Secondary lead, derived principally from scrapped lead-acid batteries, accounted for 77% of refined lead production in the United States. Nearly all the secondary lead was produced by 7 companies operating 15 smelters.

During 2000, U.S. Government agencies issued several proposed and final rules on matters affecting the lead industry. The rules included issuance of new standards for identifying lead in paint, dust and soil, issuance of new motor vehicle standards to address battery safety in electric vehicles (EVs), revision of regulations for hunting and sport fishing in the National Wildlife Refuge System, and approval of new, nontoxic forms of ammunition for hunting water fowl. In addition, the availability of transition assistance was announced with regard to implementation of the new requirements for notification, evaluation, and reduction of lead-based paint hazards in federally owned residential property and housing receiving federal assistance. A notice of funding availability also was announced in which proposals from Indian Tribes were solicited to conduct blood-lead screening tests on tribal children.

Lead was consumed in about 140 plants to manufacture end-use products, including batteries, ammunition, covering for power and communication cable, building-construction materials, and solders for motor vehicles, metal containers, and electrical/electronic components and accessories.

Lead-acid batteries, including starting-lighting-ignition (SLI) and industrial types, continued to be the overwhelmingly dominant use of lead, accounting for about 87% of reported lead consumption. SLI battery shipments in 2000 totaled 98 million units. This total included original equipment and replacement automotive-type batteries. An estimated 1.04 million metric tons (Mt) of lead was contained in SLI batteries shipped during the year.

Monthly sales of lead from the National Defense Stockpile (NDS) continued during 2000. Sales totaled about 32,000 metric tons (t) (35,300 short tons), leaving about 220,000 t (242,000 short tons) in the NDS at yearend.

Lead prices continued to decline throughout the year. The average London Metal Exchange (LME) and North American Producer prices were down by $0.022 per pound and $0.002 per pound, respectively, in 2000, from the average prices of $0.228 per pound and $0.437 per pound, respectively, in 1999.

Of the 42 countries in which lead was mined, the top 5 accounted for 70% of the world's total production of 3.1 Mt. Australia was the largest producer, with 23% of the world total,

Lead in the 20th Century

In 1900, the United States was the largest producer of refined lead in the world, accounting for about 29% of world production. Other significant producers included Australia, Germany, Mexico, and Spain. Mine production of lead was conducted principally in the States of Colorado, Idaho, Kansas, Missouri, Montana, and Utah, with the Coeur d'Alene mining district in Idaho contributing about 28% of the total production. The demand for lead was essentially in balance with domestic production, necessitating very little reliance on imports. Uses of lead in the United States were primarily for ammunition, brass, burial vault liners, ceramic glazes, leaded glass and crystal, paints or other protective coatings, pewter, and water lines and pipes. The use of recycling as a source of refined lead had begun as early as 1867. By 1900, recycled lead continued to represent a small but undifferentiated portion of the total production of refined lead. In 1907, as further information became available, lead recycling was estimated to represent about 6% of the total production of refined lead in the United States.

In 2000, the United States continued to be a major producer of refined lead, representing about 23% of the total world production. Other major producers of refined lead were Australia, Canada, China, France, Germany, Italy, Japan, and the United Kingdom. Nearly 77% of the U.S. production was derived through recycling. The predominant source of lead scrap for recycling was spent lead-acid batteries. Mine production of lead was conducted principally in Alaska and Missouri. A continuing strong demand for lead, particularly in the battery sector where 87% was used, required that the United States depend on imports and purchases from the U.S. Defense Stockpile for about 22% of its lead consumption. Lead was also consumed in end-use products including ammunition, building construction materials, sheet and oxides for radiation shielding, solders, and automobile wheel weights.

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followed by China, 18%; the United States, 15%; Peru, 9%; and Mexico, 5%.

Worldwide reserves of lead contained in demonstrated resources from producing and nonproducing deposits at yearend were estimated to be 64 Mt by the U.S. Geological Survey (USGS). Reserves for the three largest producers in the world, Australia, the United States, and China, were about 15 Mt, 6.5 Mt, and 9 Mt, respectively. The reserve base (reserves plus measured and indicated resources that are marginally economic and some of those that are currently subeconomic) for Australia and China was 28 Mt and 30 Mt, respectively. The reserve base for the United States was 20 Mt. The total world reserve base at the end of 1999 was estimated to be 130 Mt.

The USGS has issued a report on undiscovered gold, silver, copper, lead, and zinc deposits in the United States (U.S. Geological Survey, 2000). In the report, the estimate of the amount of lead in undiscovered mineral deposits ranged from greater than 47 Mt (90% probability) to greater than 130 Mt (10% probability). The mean estimate of lead in undiscovered deposits was 85 Mt with nearly one-half thought to be contained in undiscovered sedimentary exhalative deposits. Other major lead deposit types considered in the report were Mississippi Valley and polymetallic replacement deposits. Identified U.S. lead resources were estimated to be 51 Mt. Coupled with an estimated past lead production of 41 Mt, the total discovered lead resource in the United States was estimated to be 92 Mt.

Legislation and Government Programs

Monthly sales of lead from the NDS continued during 2000. As a result of these sales and the delivery of previously committed inventory, lead disposal from stockpile inventory during 2000 totaled about 32,000 t (35,300 short tons). The Defense National Stockpile Center's (DNSC) Annual Materials Plan (AMP) approved by the U.S. Congress for fiscal year 2000 (October 1, 1999, to September 30, 2000) included a maximum sales authority for lead of 54,400 t (60,000 short tons). Under this authority, disposal of lead from NDS inventory during the first 9 months of calendar year 2000 was 24,200 t (26,700 short tons). The AMP approved by the U.S. Congress for fiscal year 2001 (October 1, 2000, to September 30, 2001) also included a maximum sales authority for lead of 54,400 t (60,000 short tons). Under the fiscal year 2001 authority, disposal of lead from NDS inventory during the last 3 months of 2000 amounted to 7,800 t (8,600 short tons), leaving about 220,000 t (242,000 short tons) of lead at yearend. A solicitation was issued by the DNSC in July 2000 for the sale of lead from the NDS in negotiated long-term contracts extending for a contract period of 360 calendar days. This solicitation included several grades of lead totaling about 23,600 t (26,100 short tons).

During 2000, U.S. Government agencies issued several proposed and final rules, announced funding availability, and requested specific information and comments from the public on matters affecting the lead industry. A State Government agency also initiated enforcement of a ban on disposal of certain electronic waste materials containing lead. In February, the U.S. Environmental Protection Agency (EPA) solicited preapplication grant proposals from Indian tribes to conduct blood-lead screening for tribal children and to conduct lead awareness outreach activities for Indian tribes. Grants totaling approximately $2 million were to be awarded to perform these activities and to encourage continuation of these activities in the future. The grants were to be awarded based upon evaluation of the preapplication proposals (U.S. Environmental Protection Agency, 2000a).

In December, the EPA announced new national standards for identifying dangerous levels of lead in paint, dust, and soil. Under these new standards, Federal agencies (including the U.S. Department of Housing and Urban Development (HUD) as well as State, local, and tribal governments) will have new uniform benchmarks on which to base remedial actions taken to safeguard the public from exposure to lead. The standards also will apply to other Federal lead provisions, such as EPA real estate disclosure requirements presently in place for individuals selling or renting a home or an apartment and EPA programs engaged in the cleanup of toxic waste. In addition, the standards will provide landlords, parents, and childcare providers with information on specific lead hazard levels, so that informed decisions can be made on such levels of lead found in homes, yards, or play areas. Under the new standards, lead is considered a hazard if levels are greater than the following: 40 micrograms of lead per square foot in dust on floors; 250 micrograms of lead per square foot in dust on interior window sills; and 400 parts per million (ppm) in the bare soil of children's play areas or 1,200 ppm average in the bare soil in the remainder of the yard. Identification of lead hazards through these standards will allow inspectors and risk assessors to assist property owners in deciding on appropriate processes to correct lead-related problems. These processes may include lead paint abatement, covering or removing lead-containing soil, and professional cleaning of lead dust. The EPA's new standards are in accordance with section 403 of the Toxic Substances Control Act, as amended by the Residential Lead-Based Paint Hazard Reduction Act of 1992, also known as Title X (U.S. Environmental Protection Agency, 2000b).

In August, the EPA issued a notice of availability and solicitation of public comment on the Agency's draft National Action Plan to promote further voluntary reductions of use and exposure to alkyl-lead compounds. Alkyl-lead (e.g. tetraethyl and tetramethyl lead) is used as a fuel additive to reduce "knock" in combustion engines and also to help lubricate internal engine components and protect intake and exhaust valves against recession. Alkyl-lead additives are permitted for use in aviation gasoline for general aviation (piston-engine) aircraft and in fuels for racing vehicles, and nonroad vehicles such as farm machinery, marine vessels, construction equipment, and recreational vehicles. The National Action Plan was developed pursuant to the EPA's Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Pollutants (U.S. Environmental Protection Agency, 2000c). The EPA had issued its final rule on the reporting thresholds for certain other PBT chemicals in October 1999 but had excluded any final action on the alkyl-lead compounds in this final rule (U.S. Environmental Protection Agency, 1999).

In September, HUD announced the availability of transition assistance with regard to the implementation of HUD's new requirements for notification, evaluation, and reduction of lead-based paint hazards in federally owned residential property and housing receiving Federal assistance. The new requirements (Lead Safe Housing Regulations) implement Se

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ctions 1012 and 1013 of the Residential Lead-Based Paint Hazard Reduction Act of 1992, which is Title X of the Housing and Community Development Act of 1992. The final rule on these requirements was issued by HUD in September 1999 with an implementation date effective September 15, 2000. In order to ensure that adequate service providers were available to conduct lead-based paint hazard evaluation and reduction activities safely, effectively, and efficiently under the new requirements, HUD developed a three-component transition assistance policy. The first component authorized a 6-month transition period for program participants in jurisdictions that notified HUD by November 15, 2000, that they lacked the capacity to implement one or more provisions of the Lead Safe Housing Regulation. The second provided a 12-month transition period for post-1960 properties occupied by children under 6 years of age receiving only tenant-based rental assistance. The third component provided a twelve-month transition period for properties receiving Federal rehabilitation assistance greater than $25,000 that are occupied by the elderly, and where no child under 6 years of age resided or was expected to reside. A submission by a jurisdiction was not required in order for participants to be eligible under the second and third components of the transition assistance policy (U.S. Department of Housing and Urban Development, 2000).

In May, the U.S. Department of the Interior, Fish and Wildlife Service, issued its final rule on the 1999-2000 Refuge-Specific Hunting and Sport Fishing Regulations. Under this rule, a revision was made requiring that individuals may possess only approved nontoxic shot while on Waterfowl Production Areas and certain other defined areas of the National Wildlife Refuge System. In addition, in areas where the hunting of wild turkey and deer was permitted, lead-containing shot or slugs could be used unless prohibited by refuge-specific regulations and/or State law. Excluded from the final rule was the establishment of lead-free fishing areas. The Fish and Wildlife Service planned to address this issue in a separate final rule at a later date (U.S. Department of the Interior, 2000d).

In further actions, the Fish and Wildlife Service issued a final rule approving the use of tungsten-matrix shot, and a proposed rule approving tungsten-nickel-iron shot as nontoxic forms of ammunition for hunting waterfowl and coots (U.S. Department of the Interior, 2000a, b). A proposed rule giving temporary approval for the use of tin shot in hunting waterfowl and coots during the 2000-2001 hunting seasons also was issued by the Fish and Wildlife Service (U.S. Department of the Interior, 2000c).

The U.S. Nuclear Regulatory Commission (NRC) amended its regulations in October to add the NAC Universal Storage System (NAC-UMS) to the list of approved spent nuclear fuel storage casks. The amendment allows the holders of power reactor operating licences to store spent fuel in this approved cask system under a general license. Simultaneous with the approval of the NAC-UMS system, the NRC issued a final Safety Evaluation Report and a Certificate of Compliance for the cask system, effective November 20, 2000. Interlocking lead bricks are used in the transfer cask portion of the system. These bricks effectively shield gamma radiation from being emitted from the spent nuclear fuel during loading, unloading, and transfer operations between the transportable storage canister and the vertical concrete cask storage components of the system (U.S. Nuclear Regulatory Commission, 2000).

The U.S. Department of Transportation, National Highway Traffic Safety Administration, issued a final rule in September establishing a new Federal motor vehicle safety standard, FMVSS No. 305, that addresses electrolyte spillage, battery retention, and electrical shock protection in crashes involving EVs. In order to conform to the safety standards, electrolyte spillage of not more than 5 liters will be allowed outside the passenger compartment, and no visible trace of electrolyte will be permitted to spill into the passenger compartment in controlled impact tests. Electrolyte spillage is measured from the moment the vehicle ceases motion following a barrier impact test until 30 minutes thereafter, and throughout any static rollover after barrier impact. Also, no part of the battery component system positioned outside the passenger compartment will be permitted to enter the passenger compartment as a result of the impact. In addition, electrical isolation must be maintained between the battery system and the electrically conductive structure of the EV after impact, such that the electrical resistance is not less than 500 ohms per volt. The final rule applies to all EVs that have a propulsion power source greater than 48 volts and a gross vehicle weight rating of 4,536 kilograms (kg) or less. The final rule will become effective October 1, 2001 (U.S. Department of Transportation, 2000).

In April, the State of Massachusetts began enforcing a ban on the disposal of cathode ray tubes (CRTs) at landfills, transfer stations, and incinerators. The action was taken by the State's Department of Environmental Protection as a measure to prepare for the projected significant increase in the level of CRT disposals in unwanted older televisions and computer monitors. One of the factors considered in the State's concern over the disposal of the CRTs is the environmental consequences of the relatively high lead content associated with them. The lead, an important material in CRTs that protects the consumer from exposure to harmful radiation, is present in CRTs at a level of about 2 to 4 kg. Environmental officials in Massachusetts were hopeful that the ban on discarding CRTs would prompt a strong interest in reuse and recycling of CRT components (American Metal Market, 2000b).

Production

Primary.—In 2000, domestic mine production of lead decreased by about 46,000 t, or 9%, compared with that of 1999. A significant portion of the decline was attributed to planned cutbacks in production at several mines in Missouri. The major share of the U.S. mine output of lead continued to be derived from production in Alaska and Missouri. Appreciable lead mine production also was reported in Idaho and Montana. Domestic mine production data were collected from a voluntary survey on lode-mine production of gold, silver, copper, lead, and zinc by the USGS. All lead-producing mines responded to this survey. The lead concentrates produced from the mined ore were processed into primary metal at two smelter-refineries in Missouri and a smelter in Montana (tables 1-4).

The Doe Run Resources Corp., St. Louis, MO, produced primary lead at two smelter-refinery facilities in Missouri. Concentrates for the smelter-refineries were provided from six Doe Run mills that were supplied with ore mined from eight

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production shafts along the Viburnum Trend in southeastern Missouri. In addition, concentrate for the smelter-refineries was purchased in the open market. The open market purchases served to supplement Doe Run's announced reductions in mine production in January and April. As of October 31, 2000, the company's proven and probable U.S. ore reserves were about 58 Mt, grading 5.78% lead, 1.25% zinc, and 0.23% copper. In fiscal year 2000, ending October 31, 2000, Doe Run shipped about 510,000 t of refined lead and lead alloy products, including recycled lead produced at its secondary smelter in southeastern Missouri. Doe Run's issued and outstanding stock are indirectly owned by The Renco Group, Inc., a New York-based, privately held company with investments in natural resources and industrial operations. During 2000, the company continued exploration drilling in the vicinity of all eight of its mines in the Viburnum Trend region. Exploration activity was carried out both at the surface and underground, with an intent to delineate additional ore reserves. Drilling also was carried out within most of Doe Run's mines to access ore beyond the current mining areas (Doe Run Resources Corp., 2000, p. 1-7; Metal Bulletin, 2000a, b).

ASARCO Inc., a wholly owned subsidiary of Grupo Mexico, S.A. de C.V., continued to operate the custom primary lead smelter in East Helena, MT, during the year. By midyear, the quantity of lead bullion sold from smelter production was about 32,600 t, an increase of about 8% compared with the same period in 1999 (Grupo Mexico, S.A. de C.V., 2000).

Cominco Alaska Inc., a wholly owned subsidiary of Cominco Ltd., Toronto, Canada, operated the Red Dog zinc-lead mine in northwestern Alaska under a leasing agreement with NANA Regional Corp., the sole owner of the property. NANA is a corporation organized under the provisions of the Alaska Native Claims Settlement Act. The average mill recovery of lead at Red Dog was 58% in 2000, compared with 59% in 1999. Overall production of lead concentrate decreased by 8% to about 140,000 t at an average concentrate grade of 59.6% lead. Delineation drilling during the year outlined the underground Anarraaq deposit that was discovered in 1999 about 10 kilometers northwest of Red Dog. Anarraaq is estimated to contain an inferred resource of 17.2 Mt grading 15.8% zinc and 4.8% lead. A second area of mineralization also was discovered near Anarraaq during the year and, in addition, gravity surveys and borehole geophysics further identified several new target areas of mineralization. The five deposits at Red Dog's mineralized center (Main Zone, Aqqaluk, Paalaaq, Qanaiyaq (formerly Hilltop), and Anarraaq) were estimated to contain total resources of 148 Mt of ore grading 16.6% zinc and 4.5% lead. A major program of in-fill drilling and metallurgical tests conducted on the Aqqaluk deposit during 2000 resulted in the reclassification of some of the Aqqaluk mineralization to the probable reserve category. Proven ore reserves at Red Dog (Main Zone) in 2000 were estimated to be 41.9 Mt grading 19.2% zinc and 5.2% lead. Probable reserves at Aqqaluk were estimated to be 56.1 Mt grading 16.6% zinc and 4.1% lead. In other developmental activities during the year, Cominco, in cooperation with the U.S. Army Corps of Engineers, continued their 2-year study to determine the viability of upgrading Red Dog's existing shipping facility into a deep-water port. The study is addressing the feasibility of dredging a deep channel through the shallow coastal waters to the shoreline in order to accommodate ocean-going vessels, thus permitting direct loading of the concentrate onto ships. The study is due to be completed in 2001 (Cominco Ltd., 2000a, p. 11-22).

Cominco also continued the development of the Pend Oreille zinc-lead mine near Metaline Falls, WA. In September, the Board of Directors of Canada's Cominco Ltd. endorsed the decision made by the Board of Directors of Cominco American Inc., a wholly owned subsidiary of Cominco Ltd., to rebuild the mill and reopen the mine. The 2-year construction project began in October 2000 and involved refurbishment of the existing concentrator, sinking of an internal mine shaft, and conducting other mining preparation activities. Production from the mine is scheduled to begin in September 2002 and is expected to yield 84,000 metric tons per year (t/yr) of zinc concentrate and 13,000 t/yr of lead concentrate. The concentrates will be shipped to Cominco's nearby Trail, B.C., facility for further processing. Cominco officials anticipate that the Pend Oreille Mine will have a minimum life of 10 years and will provide employment for about 170 people (Cominco Ltd., 2000b).

Hecla Mining Co., Coeur d'Alene, ID, operated the Lucky Friday Mine in Mullan, ID, throughout 2000. Lucky Friday is an underground silver-lead mine 100% owned by Hecla that has been a producing mine for Hecla since 1958. A second full year of production was carried out at the adjacent Gold Hunter ore body, effectively increasing lead production by 15.7% to a level of 29,000 t. Ore was processed during the year in a conventional flotation mill at a full-capacity rate of about 1,000 metric tons per day (t/d). Both silver-lead concentrates and zinc concentrates were produced at the mill, with 94% of the silver, 93.6% of the lead, and 41.4% of the zinc being economically recovered. In the fourth quarter of 2000, Hecla recorded a financial adjustment to the Lucky Friday Mine, thereby reducing the carrying value of mine property, plant structures, and equipment. The adjustment was necessitated by continuing low silver and lead prices. In addition, as a result of the low metal prices, Hecla's Board of Directors deferred a decision in the fourth quarter of the year to approve the additional capital expenditures that were needed to carry out development of another area of the mine. Total proven and probable ore reserves at the Lucky Friday and the Gold Hunter deposits were about 1.2 Mt grading 10.7% lead at yearend 2000 compared with 1.5 Mt grading 9.6% lead at yearend 1999.

Hecla Mining also held a 29.7% interest in the Greens Creek Mine on Admiralty Island, near Juneau, AK, through a joint-venture arrangement with Kennecott Greens Creek Mining Co., the manager of the mine, and Kennecott Juneau Mining Co., both wholly owned subsidiaries of Kennecott Corp. At Greens Creek, about 1,500 t/d of ore was mined from the underground 200 South, Southwest, and West ore zones and milled on-site to yield lead, zinc, and bulk concentrates, as well as a gold-silver doré. Total production of lead in concentrate was about 22,800 t in 2000 compared with about 23,100 t in 1999. Estimated reserves at the Greens Creek Mine at yearend 2000 were 9.1 Mt grading 4.4% lead. Drilling continued during 2000, serving to essentially replace the quantity of reserves depleted through production during the year (Hecla Mining Co., 2000, p. 6-12).

Secondary.—Domestic secondary production increased about 2% in 2000. Secondary lead accounted for 77% of domestic lead refinery production compared with 76% in 1999. Lead

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recovered from scrap lead-acid batteries continued at a high level and accounted for 90% of all lead produced from secondary sources. The domestic secondary statistics were derived by the USGS from a combined secondary producer and consumer survey that included data from monthly and annual surveys. All of the 18 companies producing secondary lead, exclusive of that produced from copper-based scrap, were surveyed; 16 responded, representing more than 99% of the total production of secondary lead. Of the total lead recycled in 2000, about 98% was produced by 7 companies operating 15 plants in Alabama, California, Florida, Indiana, Louisiana, Minnesota, Missouri, New York, Pennsylvania, Tennessee, and Texas. Production and consumption for the nonrespondents were estimated by using prior-year levels as a basis (tables 1, 5-9).

Exide Corp., Reading, PA, completed its acquisition of GNB Technologies, Inc., Atlanta, GA, on September 29, 2000. As a result of the purchase, and following shareholder approval, Exide Corp. was renamed Exide Technologies. GNB had supplied a significant portion of the industrial batteries used in the North American market. Thus, the purchase allowed Exide to reenter the North American industrial battery business. GNB also was a leading supplier of automotive batteries for both the original equipment and replacement battery markets. Following the acquisition, Exide also announced several initiatives designed to restructure the newly formed company: consolidation of automotive battery manufacturing facilities in the United States; consolidation of industrial battery operations in Europe; closure of several distribution centers and branch locations by the end of 2000; and downsizing and relocation of new headquarters to Princeton, NJ, from Reading, PA (Exide Technologies, 2000).

In January, Johnson Controls, Inc., Milwaukee, WI, signed new tolling agreements to recover lead from spent lead-acid batteries for its battery business on the west coast of the United States. Reportedly, the processing of the spent battery units was to be divided between the secondary smelter plants of RSR Corp. at City of Industry, CA, and GNB Technologies, Inc. at Vernon, CA. The tolling agreements were expected to be in effect for 1 year (Ryan's Notes, 2000).

Consumption

Reported consumption of lead increased by 2% as the demand for lead in storage batteries continued to increase. The demand for lead declined in a number of other end uses, including bearing metals, cable covering, and construction materials, such as caulking lead, pipes, traps, and other extruded products. Consumption of lead in SLI- and industrial-type lead-acid storage batteries represented 87% of the total reported consumption of lead. Industrial-type batteries included stationary batteries (such as those used in uninterruptible power-supply equipment for hospitals, computer and telecommunications networks, and load-leveling equipment for commercial electrical power systems) as well as traction batteries (such as those used in industrial forklifts, airline ground equipment, and mining vehicles). Of the 108 consuming companies to which a USGS survey request was sent, 83 responded, representing about 96% of the total reported U.S. lead consumption.

The Battery Council International reported SLI-type battery shipments of 98 million units in 2000 compared with 100 million units in 1999 (Amistadi, 2001, p. 12-31). The totals included original equipment and replacement automotive-type batteries. By using an estimate of 10.6 kg (23.3 pounds) of lead per unit, the SLI shipments in 2000 accounted for about 1.04 Mt of lead. SLI batteries included those used for automobiles, buses, trucks, tractors, motorcycles, and marine craft. (tables 6-13).

World Review

World production of refined lead increased to 6.46 Mt in 2000 from 6.13 Mt in 1999. Other statistics for 2000, as reported by the International Lead and Zinc Study Group, are as follows: world consumption increased to 6.46 Mt from 6.24 Mt in 1999; commercial stocks of refined lead in industrialized countries were 421,000 t, or 4 weeks of consumption, at yearend 2000 compared with 472,000 t at yearend 1999 and 418,000 t at yearend 1998; and significant exports of refined lead to industrialized countries from developing Asian countries, notably China, continued during 2000, increasing by about 10%, to 628,000 t, compared with those of 1999 (International Lead and Zinc Study Group, 2001, p. 6-21).

Lead prices exhibited a declining trend for the fourth consecutive year. The average LME and North American Producer prices were down by $0.022 per pound and $0.002 per pound, respectively, in 2000, from the average prices of $0.228 per pound and $0.437 per pound, respectively, in 1999.

The structure of the lead mining and refining industries was affected by a number of changes, including the opening and development of new facilities, as well as the closing, reopening, expanding, selling, and modernizing of existing facilities (tables 14, 15).

New Mines, Plants, Properties, Resources.—Ireland's Lisheen lead-zinc mine in County Tipperary Ireland was officially opened in late June (Mining Journal, 2000e). By yearend, the mine was being operated at about 70% of capacity. Lisheen was expected to reach full production capacity in the second quarter of 2001, yielding 300,000 t/yr of zinc concentrate and 40,000 t/yr of lead concentrate over a mine life of 14 years. During the first half of 2000, about 58,000 t of zinc concentrate and 19,000 t of lead concentrate were produced at Lisheen. The Lisheen mining operation is a 50-50 joint venture between Ivernia West plc and Anglo American plc in which Anglo American's subsidiary, Anglo Base Metals Ltd., operates the mine (Platt's Metals Week, 2000d).

Canada's Minco Mining and Metals Corp. and Teck Corp. continued a drilling program at the White Silver Mountain polymetallic property in China. Drilling results disclosed in March showed lead contents of up to 10.0%. Earlier drill results had revealed mineralization containing between 3.9% and 4.4% lead. During the remainder of the year, the joint-venture partners developed further the underground region of mineralization to permit additional exploration drilling and also conducted a surface geophysical program (Mining Journal, 2000b).

Canada's Noranda Inc. proceeded with a full feasibility study in May on the development of the Lady Loretta zinc-lead-silver deposit in Queensland, Australia, through its Australian

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subsidiary Noranda Pacific. Noranda had an option to acquire a 75% interest in the Lady Loretta project from Melbourne-based Buka Minerals Ltd., and had been actively exploring the deposit since early 1999. A decision by Noranda to complete the full feasibility study prior to the option expiration date suggested that development of the Lady Loretta deposit was likely to occur. A drilling program completed by Noranda in the first quarter of the year reportedly indicated a significant increase in the resource estimate at Lady Loretta. Prior to the option agreement the identified resources were 8.2 Mt, averaging 17.6% zinc, 8.4% lead, and 122 grams per ton silver. Although the deposit is very high grade, its development has been hindered thus far by the extremely fine-grained characteristic of the ore that has made it difficult to process using conventional technology (Metal Bulletin, 2000k).

In June, Exide Corp., Reading, PA, announced plans to construct a lead-acid battery manufacturing facility in Bawal, India. The plant, located in the State of Haryana, will be used to manufacture batteries for export, with sales targeted mostly in Southeast Asia through Exide's subsidiary, Chloride Batteries Co. in Singapore. The latter company's strategic partner, Shin Kobe Electric Co., has expressed interest in sourcing battery supplies from India, which would benefit the Exide project (Metal Bulletin, 2000d).

EuroZinc Mining Corp., Vancouver, Canada, reported positive results from a feasibility study completed in June on its Aljustrel project in southern Portugal. Results of the study indicated that about 65,800 t of zinc, 15,400 t of lead, and an appreciable quantity of silver could be produced annually over the first 9 years of operation at Aljustrel's Feitas and Moinho deposits. Aljustrel had operated for several years in the early 1990s. However, low recoveries and inefficient mining methods, combined with low metal prices, forced the closure of the mine. Since that time, the mill and related facilities have been maintained in good condition. With most infrastructure already in place, mine production at Aljustrel could begin as early as the fourth quarter of 2001, with initial feed to the mill coming from the Moinho deposit (Northern Miner, 2000a).

In July, Canada's Vancouver-based Expatriate Resources Ltd. completed the initial process metallurgy and concentrate marketing stages for its Finlayson project in Yukon Territory. The project combines development of the recently acquired Kudz Ze Kayah deposit and the Wolverine deposit, the latter being 40% owned by Atna Resources Ltd. Flotation test results confirmed that ores from Kudz Ze Kayah and Wolverine can be combined to yield improved flotation results over those obtained using only the Wolverine ore as feed material. Based on assessments of a combined mill feed of 4,250 t/d, production of about 200,000 t of zinc concentrate, and 33,000 t of lead concentrate, each containing 55% of the respective metal, were considered possible per year. A prefeasibility study completed at the end of the year outlined probable reserves of 14.6 Mt at Finlayson, grading 7.2% zinc, 1.5% lead, and significant quantities of copper, gold and silver (Mining Journal, 2000d; Northern Miner, 2000b).

Apex Silver Mines Ltd., Denver, CO, received initial assay results in midyear from a drilling program at its Platosa lead-silver-zinc property in central Mexico. The intersection of massive and semimassive sulfide mineralization revealed lead concentrations ranging from 3.6% to 25.2% and zinc concentrations ranging from 0.1% to 17.6%. Apex, through its Mexican subsidiary Mineras de Cordilleras S.de R.L. de C.V., owns a 65% interest in Platosa. Also, Apex reportedly was in the process of increasing its land holdings in the Platosa region where it also owns the adjacent Saltillera property (Mining Journal, 2000g).

In November, Canada's Vancouver-based International Annax Ventures, Inc. (IAV) received assay results from its drilling program at the Sopokomil polymetallic deposit, part of the Dairi property in northern Sumatra, Indonesia. Drilling results showed the intersection of both massive sulfide and carbonate-hosted Mississippi Valley-type mineralization with lead concentrations ranging from 8.4% to 15.2% and zinc concentrations ranging from 6.7% to 23.3%. Australia's Perth-based Herald Resources Ltd. holds a 71% undiluted capital interest in IAV, and was manager of Dairi until May 2000. At that time, Cominco Ltd. began management of the property in accordance with an agreement to earn a 40% interest in the property from IAV in exchange for a 5-year monetary investment in the property (Mining Journal, 2000c, h).

In August, Australian base metals miner MIM Holdings Ltd. reported that its 70%-held McArthur River zinc-lead-silver mine achieved a record production of about 117,000 t of zinc and 30,000 t of lead in concentrate in the 1999-2000 fiscal year. In addition, Mount Isa's output of lead contained in lead-silver bullion was up 7% to a level of 137,000 t compared with the previous fiscal year. MIM also reported that its George Fisher zinc-lead-silver mine at Mount Isa was on target for commissioning within budget by October 2000 (Platt's Metals Week, 2000f).

Australia's Pasminco Ltd. reported the first shipment of lead concentrate from its Century Mine in mid-August. According to Pasminco, shipments of lead concentrate were to proceed on a regular basis and were expected to reach 40,000 t by the end of the year. The company was in the process of progressively increasing its annual production to the full capacity of 880,000 t/yr of zinc concentrate and 70,000 t/yr of lead concentrate. Full production levels were anticipated by the end of 2001 (American Metal Market, 2000a).

Malaysia's Metal Reclamation Bhd began commissioning its new secondary lead smelter near Kuala Lampur in September. According to a company official, Metal Reclamation will continue to target an output of 40,000 t/yr from its existing plant, up 10,000 t from that produced in 1999. The new plant will boost the company's total production capacity to 110,000 t/yr. Metal Reclamation is mainly a processor of secondary lead and a producer of lead alloys (Platt's Metals Week, 2000e).

Denver-based Solitario Resources Corp. reported in December that its joint-venture partner Pasminco Ltd. had completed their 2000 drilling program at the Bongará zinc-lead property in northern Peru. Canada's Cominco Ltd. presently owns a 65% interest in Bongará. Assay results from drilling completed in the Florida Canyon area revealed zinc concentrations ranging from 3.4% to 15.8% and lead concentrations ranging from 2.1% to 12.4%. Pasminco was accorded the right to earn Cominco Ltd.'s 65% interest in Bongará by fully funding the 2000 drilling program and by contributing additional funds for future exploration as part of its overall commitment to the project. Solitario holds a 35% interest in Bongará (Mining Journal, 2000a).

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In November, Russia's Urals Mining and Metallurgical Co. (UGMK) reportedly was preparing to expand its metals operation to include production of lead and zinc. UGMK, formed a year ago to unite upstream and downstream copper producers in the Urals region into one of Russia's largest metal groups, plans to recover the lead and zinc from byproducts of several of the company's subsidiaries, including the Sredneuralsk copper plant, and the Krasnouralsk and Svyatogor blister copper smelters. Lead and zinc production will be distributed across three sites: Uralelectromed copper refinery, Kirovgrad Metallurgical Co., and the Upper Neivinsk non-ferrous plant. The full production system for lead and zinc is scheduled to be commissioned by September 2001. The principal source of raw material will be metallurgical dust and coke that result from processing copper concentrate and scrap at UGMK's plants. These byproducts can contain between 20% and 25% lead. It is expected that up to 12,000 t/yr of electrolytic lead will be recovered from the copper byproducts when the full production system is in operation (Metal Bulletin, 2000m).

Closings and Curtailments.—In April, Australia's Western Metals began the closure of its Hellyer Mine in Tasmania owing to the depletion of reserves at the mine. Processing of the mined ore was completed in June, at which time the facilities were placed on care-and-maintenance status. Operations at the Hellyer Mine yielded 20,400 t of zinc and 7,600 t of lead in concentrate during the first quarter of the year (Metal Bulletin, 2000n).

China's Shenyang primary lead smelter in Liaoning Province was declared bankrupt in early August as a result of prolonged financial difficulties, according to an official from the Shenyang Minmetals trading company. The Shenyang smelter has a capacity of 60,000 t/yr of refined lead but was operated below its capacity in the first 7 months of 2000 owing to financial constraints that limited the quantity of feedstock the company could purchase. Shenyang smelter officials reportedly were seeking a buyer for the facility immediately following the declaration of bankruptcy (Platt's Metals Week, 2000a).

In Kosovo, international peacekeepers closed the Zvecan primary lead smelter near Mitrovica in mid-August as a result of concerns regarding excessive emissions of lead into the environment. The smelter, part of the Trepca mining complex, was to be placed under the control of the United Nations (UN) following the closure. According to a UN official, the closure was a temporary measure that would allow a French, Swedish, and U.S. consortium, ITT Kosovo, to begin construction that would bring the facility up to environmental standards (Platt's Metals Week, 2000g).

Reopenings and Expansions.—Boliden Apirsa S.L., a subsidiary of Canada's Boliden Ltd., resumed full operation at its Los Frailes Mine near Seville, Spain, in March 2000, producing at a rate of 125,000 t/yr of zinc and 48,000 t/yr of lead contained in concentrates. Los Frailes had been forced to close in April 1998 when a tailings dam failed, flooding a significant portion of the neighboring land. The mine was restarted in June 1999 after its milling license was restored by the local administration, along with a permit to dump tailings in the adjacent Aznalcollar open pit mine (Metal Bulletin, 2000e). In October, however, Boliden Ltd. reported that its subsidiary would not invest in any further development of the open pit operations at Los Frailes and filed for the equivalent of Chapter 11 bankruptcy protection, citing appreciable financial losses since resuming operations (Mining Journal, 2000f). By yearend, Australia's Murchison United NL had entered into an agreement with Boliden Apirsa S.L. to undertake due diligence at the Los Frailes Mine. According to a Murchison spokesperson, it would be necessary to expand the open pit mine in order to access further resources and thus keep the mine in operation for an additional 10 years. Murchison planned to use its due diligence commitment to assess the extent of restructuring and the required investment to achieve this operational goal (Metal Bulletin, 2000j).

In February, Australia's Western Metals Ltd., announced plans to expand the ore processing capacity at its Pillara lead-zinc mine in the Kimberley region of Western Australia. The expansion from the existing level of 1.5 Mt/yr to a level of 2.4 Mt/yr of ore processed will effectively consolidate and reduce the cost of Western's processing operations. Expansion of the Pillara facilities was expected to be completed by January 2001 and more than compensate for the loss of production at the soon-to-be-closed, aging concentrator at Western's nearby Cadjebut Mine (Metal Bulletin, 2000o).

Israel's Hakurnas, a secondary lead producer near Ashdod, proceeded with its expansion plans to increase the quantity of lead-acid batteries recycled. According to a company spokesperson, the move to expand was made in response to the increase in demand for lead by automotive battery producers in Israel and other parts of the Middle East, as well as to the projected increase in demand for lead-acid batteries in electric vehicles during the next 10 years. The increase in secondary lead production resulting from the expansion was expected to be realized in the fourth quarter of 2000. Israel's stringent battery collection system supports the recycling of 95% of the lead consumed in the manufacture of batteries. Thus, much of the supply of spent lead-acid batteries for the Hakurnas operation was expected to be derived from domestic sources (Metal Bulletin, 2000g).

In China, plans to increase lead production were reported by several companies. The Yuguang Gold and Lead Group reported that refined lead production in 2000 was about 78,000 t, exceeding its original target by 8,000 t. Yuguang continued to construct new production facilities and, upon completion, anticipated an additional output capacity of 20,000 to 30,000 t by midyear 2001. Yuguang's refined lead exports in 2000 were about 30,000 t, nearly 10,000 t above the level exported in 1999 (Platt's Metals Week, 2000b). China's Jiyuan Gold Smelter in Henan Province began its 50,000-t/yr lead expansion project and expected to complete the project by the end of 2001. According to a company spokesperson, production at the primary lead smelter was officially scheduled to begin in early 2002. Upon completion of the expansion project, Jiyuan's capacity for production of refined lead will be raised to 120,000 t/yr (Platt's Metals Week, 2000c). Refined lead production at China's Hunan-based Shuikoushan Mining Authority reached 50,000 t in 2000, up appreciably from the levels of the previous 2 years. The company reportedly was considering renovation plans that would nearly double Shuikoushan's current lead production, but a firm schedule had not been set for initiating the 2- to 3-year renovation project (Platt's Metals Week, 2000h).

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Production at Romania's Sometra zinc-lead primary smelter in Copsa Mica reached a total of 75,000 t in 2000. Lead production represents about one-third of the total production at Sometra. Production levels at Sometra have nearly doubled since its privatization 2 years ago when production was less than 40,000 t/yr. Sometra is now 88% owned by Greek base metals producer Mytilineos Holdings S.A., which has confirmed its long-term commitment to the progress of Sometra through continued modernization and environmentally related improvements. According to a spokesperson for Sometra, a recent decision by the Romanian Government to grant the Copsa Mica area a special status to encourage investment will assist further the modernization process (Metal Bulletin, 2000l).

Transfers of Ownership, Sales Offerings, Mergers.—In September, Eco-Bat Technologies plc, a principal European lead-acid battery manufacturer, agreed to purchase Exide Technologies' Gast secondary lead smelter in Pont-Sainte-Maxence, France. Exide had purchased the Gast facility from Paris-based Cie Européene d'Accumulateurs SA in 1995, but had decided in early 2000 to sell the Gast smelter as part of a move to scale down its global operations. According to an Eco-Bat spokesperson, environmental issues had been resolved at the Gast facility and an extension of the required environmental permit had been received from the French Government. A new furnace also was installed at the facility, increasing the production capacity to 35,000 t from the previous 25,000 t (Metal Bulletin, 2000c, f).

In April, the Privatization Agency of Bulgaria (BPA) reported the receipt of one bid for the purchase of an 80% stake in the Kombinat za Czvetni Metali (KCM) primary lead-zinc smelter near Plovdiv. The bid was received from KCM's management through KCM-2000, a separate entity formed so that KCM could participate in its own privatization. According to the terms of the purchase, KCM-2000 would be permitted to extend payments for the smelter over a 10-year period with no payment due during the first year. The BPA had resumed efforts to privatize KCM in March 2000 following a failed attempt to privatize it in August 1999 (Metal Bulletin, 2000i).

In September, Irish miner Ivernia West plc achieved total control of the Magellan lead project in Western Australia through its acquisition of Polymetals Ltd. Ivernia West previously had a 15.7% interest in the project. Results of a pre-feasibility study showed a minable resource at Magellan sufficient to support a 10-year mine life. A drilling program was continued at Magellan and new ore reserves were evaluated throughout the year. It was anticipated that a full feasibility study would be completed by yearend (Metal Bulletin, 2000h).

Outlook

Total world demand for refined lead is expected to rise in 2001 by 2.2% to 6.54 Mt; in the industrialized countries alone, demand is expected to increase by 1.9% to 5.66 Mt. Demand is expected to continue to grow in Asia, rising by 4.2%, and to remain at the same level as during 2000 in Europe. Lead mine output in 2001 is predicted to rise by 1.0% worldwide to 2.99 Mt and by 1.4% in the industrialized countries to 2.29 Mt. The increase in mine output will be principally as a consequence of increases in production in Australia, Ireland, Mexico, and Sweden. Refined lead production is expected to increase by 2.3% worldwide in 2001 to 6.66 Mt, and by 2.7% in the industrialized countries to 5.21 Mt. Contributing to this increase will be projected rises in production in Australia, Canada, India, and the United States, and the commissioning of new capacity in Israel, Malaysia, and the Republic of Korea (International Lead and Zinc Study Group, 2000).

Lead-acid batteries will continue to dominate the demand for lead. The Chicago-based Battery Council International anticipates continued growth in lead-acid battery usage during the next 5 years. U.S. demand for replacement SLI lead-acid batteries is expected to grow at the rate of about 2% per year. Demand for original equipment SLI batteries, however, will be down, at least through 2001, as a result of a significant decline in passenger car and light truck production (Amistadi, 2001, p. 6-10). Demand for industrial-type lead-acid batteries will grow by 5% in 2001. The industrial battery demand will continue to grow at a rate of about 8% per year through the year 2005 for both motive power batteries and large stationary batteries. Growth in the use of the stationary batteries will be driven principally by their increasing need in the infrastructure supporting the wireless telecommunications markets and uninterruptible power supply systems. However, the rate of growth in the demand for industrial batteries will be tempered somewhat through 2005, as telecommunications companies begin to reduce capital expenditures (Cullen, 2001).

Mine production in the United States should remain constant or decline slightly in 2001 as a result of additional temporary production cutbacks at several of the larger facilities. Refined lead production from primary refineries also will decline as a result of temporary production cutbacks (Metal Bulletin, 2001). Secondary production of lead is expected to remain at a level comparable to that of 2000, but could rise by 2% to 3% should weather-related temperature extremes significantly increase the demand for replacement automotive-type batteries.

References Cited

American Metal Market, 2000a, Lead shipment leaves Century: American Metal Market, v. 108, no. 161, August 21, p. 6.

———2000b, Massachusetts enforcing ban on dumping cathode ray tubes: American Metal Market, v. 108, no. 64, April 4, p. 10.

Amistadi, R. L., 2001, 1999 battery shipment review & five-year forecast report: [Battery Council International Convention, 113th], Las Vegas, May 9, presentation handout, [33 p.].

Cominco Ltd., 2000a, Cominco Ltd. 2000 annual report: Vancouver, Canada, Cominco Ltd., 55 p.

———2000b, Cominco to reopen Pend Oreille Mine: Vancouver, Canada, Cominco news release, September 7, 1 p.

Cullen, Bob, 2001, Industrial battery forecast report: [Battery Council International Convention, 113th], Las Vegas, May 9, presentation handout, [18 p.].

Doe Run Resources Corp., 2000, Form 10-K—Fiscal year 2000: Securities and Exchange Commission, 100 p.

Exide Technologies, 2000, Exide completes acquisition of GNB Technologies: Reading, PA, Exide Technologies news release, September 29, 4 p.

Grupo Mexico, S.A. de C.V., 2000, Second quarter 2000 results: Baja California, Grupo Mexico, S.A. de C.V. news release, September 12, 14 p.

Hecla Mining Co., 2000, Form 10-K—Fiscal year 2000: Securities and Exchange Commission, 108 p.

International Lead and Zinc Study Group, 2000, ILZSG October session/forecasts: London, International Lead and Zinc Study Group press release, October 8, 6 p.

———2001, Lead and zinc statistics: Monthly Bulletin of the International Lead and Zinc Study Group, v. 41, no. 7, 68 p.

Metal Bulletin, 2000a, Doe Run cuts concentrates output, metal output unaffected: Metal Bulletin, no. 8446, January 31, p. 10.

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———2000b, Doe Run makes further cuts as low lead price takes its toll: Metal Bulletin, no. 8470, April 27, p. 6.
———2000c, Exide puts French lead smelter up for sale: Metal Bulletin, no. 8466, April 10, p. 13.
———2000d, Exide to build new lead-acid battery plant in India: Metal Bulletin, no. 8484, June 15, p. 17.
———2000e, Full production at Los Frailes set for late March: Metal Bulletin, no. 8451, February 17, p. 9.
———2000f, Gast smelter is sold to Eco-Bat: Metal Bulletin, no. 8508, September 14, p. 11.
———2000g, Hakurnas goes ahead with lead expansion: Metal Bulletin, no. 8465, April 6, p. 10.
———2000h, Ivernia West acquires Magellan Pb project: Metal Bulletin, no. 8506, September 7, p. 17.
———2000i, Management makes sole bid for KCM: Metal Bulletin, no. 8464, April 3, p. 5.
———2000j, Murchison to assess Los Frailes zinc mine: Metal Bulletin, no. 8531, December 4, p. 5.
———2000k, Noranda commits to undertake study on Queensland zinc-lead-silver project: Metal Bulletin, no. 8478, May 25, p. 8.
———2000l, Sometra boosts zinc-lead production: Metal Bulletin, no. 8536, December 21, p. 5.
———2000m, Urals copper producers to expand into lead and zinc: Metal Bulletin, no. 8523, November 6, p. 7.
———2000n, Western Metals to close zinc-lead mine: Metal Bulletin, no. 8470, April 27, p. 7.
———2000o, Western Metals to expand Pillara plant and close Cadjebut: Metal Bulletin, no. 8452, February 21, p. 6.
———2001, Doe Run cuts lead output by 80,000 tpy: Metal Bulletin, no. 8557, March 12, p. 3.
Mining Journal, 2000a, Bongará results for Solitario: Mining Journal, v. 335, no. 8612, December 8, p. 453.
———2000b, Chinese assays: Mining Journal, v. 334, no. 8574, March 17, p. 213.
———2000c, Dairi intercepts: Mining Journal, v. 335, no. 8610, November 24, p. 413.
———2000d, Finlayson study: Mining Journal, v. 335, no. 8591, July 14, p. 27.
———2000e, Lisheen officially opens: Mining Journal, v. 334, no. 8589, June 30, p. 507.
———2000f, Los Frailes stalls: Mining Journal, v. 335, no. 8603, October 6, p. 275.
———2000g, Platosa assay results: Mining Journal, v. 335, no. 8592, July 21, p. 45.
———2000h, Sopokomil results: Mining Journal, v. 335, no. 8590, July 7, p. 8.
Northern Miner, 2000a, Positive feasibility for Eurozinc's Aljustrel: Northern Miner, v. 86, no. 18, June 26-July 2, p. 1.
———2000b, Positive study tabled for Finlayson: Northern Miner, v. 86, no. 39, November 20-26, p. 1.
Platt's Metals Week, 2000a, China's Shenyang lead smelter bankrupt: Platt's Metals Week, v. 71, no. 33, August 14, p. 12.
———2000b, China's Yuguang lead production 8,000 mt over target: Platt's Metals Week, v. 71, no. 52, December 25, p. 7.
———2000c, Jiyuan to complete Pb expansion in 2001: Platt's Metals Week, v. 71, no. 39, September 25, p. 14.
———2000d, Lisheen delays full zinc output: Platt's Metals Week, v. 71, no. 46, November 13, p. 10.
———2000e, Malaysian plant to be commissioned: Platt's Metals Week, v. 71, no. 36, September 4, p. 7.
———2000f, MIM's McArthur River has record output: Platt's Metals Week, v. 71, no. 32, August 7, p. 5.
———2000g, Polluting Kosovo lead smelter closed: Platt's Metals Week, v. 71, no. 34, August 21, p. 5.
———2000h, Shuikoushan sees 10% rise in H1 lead: Platt's Metals Week, v. 71, no. 23, June 5, p. 6.
Ryan's Notes, 2000, JCI's new west coast tolling contracts: Ryan's Notes, v. 6, no. 2, January 10, p. 4.
U.S. Department of Housing and Urban Development, 2000, Requirements for notification, evaluation and reduction of lead-based paint hazards in federally owned residential property and housing receiving federal assistance—Notice of transition assistance: Federal Register, v. 65, no. 176, September 11, p. 54858-54859.
U.S. Department of the Interior, 2000a, Migratory bird hunting—Approval of tungsten-matrix shot as nontoxic for hunting waterfowl and coots: Federal Register, v. 65, no. 173, September 6, p. 53936-53940.
———2000b, Migratory bird hunting—Approval of tungsten-nickel-iron shot as
nontoxic for hunting waterfowl and coots: Federal Register, v. 65, no. 210, October 30, p. 64650-64654.
———2000c, Migratory bird hunting—Temporary approval of tin shot as nontoxic for hunting waterfowl and coots during the 2000-2001 season—Final rule: Federal Register, v. 65, no. 236, December 7, p. 76885-76888.
———2000d, 1999-2000 Refuge-specific hunting and sport fishing regulations—Final rule: Federal Register, v. 65, no. 93, May 12, p. 30771-30795.
U.S. Department of Transportation, 2000, Federal motor vehicle standards: Federal Register, v. 65, no. 188, September 27, p. 57980-57992.
U.S. Environmental Protection Agency, 1999, Persistent Bioaccumulative Toxic (PBT) chemicals; Final rule: Federal Register, v. 64, no. 209, October 29, p. 58665-58753.
———2000a, Childhood blood-lead screening and lead awareness (Educational) outreach for Indian Tribes—Notice of funds availability: Federal Register, v. 65, no. 36, February 23, p. 8967-8970.
———2000b, EPA announces tough new standards for lead: Washington, DC, U.S. Environmental Protection Agency Headquarters press release, December 26, 2 p.
———2000c, National action plan for alkyl-lead—Notice of availability and solicitation of public comment: Federal Register, v. 65, no. 166, August 25, p. 51823-51825.
U.S. Geological Survey, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.
U.S. Nuclear Regulatory Commission, 2000, List of approved spent fuel storage casks—NAC-UMS addition: Federal Register, v. 65, no. 203, October 19, p. 62581-62599.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Lead. Ch. in Mineral Commodity Summaries, annual.
Lead. Ch. in Minerals Yearbook, annual.
Lead. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Lead. Mineral Industry Surveys, monthly.

Other

DNSC News Releases.
International Lead and Zinc Study Group.
Lead Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platt's Metals Week.
U.S. Department of Commerce.

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TABLE 1
SALIENT LEAD STATISTICS 1/

(Metric tons, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production:					
Mine, recoverable lead content 2/	426,000	448,000	481,000	503,000	457,000
Value thousands	$459,000	$460,000	$480,000	$485,000	$439,000
Primary lead (refined):					
Domestic ores and base bullion	326,000 3/	343,000 3/	337,000	350,000	341,000
Foreign ores and base bullion	W	W	W	W	W
Secondary lead (lead content)	1,070,000	1,110,000	1,120,000	1,110,000	1,130,000
Exports (lead content):					
Lead ore and concentrates	59,700	42,200	72,400	93,500	117,000
Lead materials, excluding scrap	121,000	104,000	100,000	103,000	92,000
Imports for consumption:					
Lead in ore and concentrates	6,570	17,800	32,700	12,300	31,200
Lead in base bullion	5	25	464	90	65
Lead in pigs, bars, reclaimed scrap	268,000	265,000	267,000	311,000	356,000
Stocks, December 31:					
Primary lead	8,140 3/	11,900 3/	10,900	12,300	18,600
At consumers and secondary smelters	72,100	89,100	77,900	78,700 r/	104,000
Consumption of metal, primary and secondary	1,540,000	1,620,000	1,630,000	1,680,000	1,720,000
Price, North American cents per pound producer average, delivered 4/	48.83	46.54	45.27	43.72	43.57
World:					
Production:					
Mine thousand metric tons	3,090	3,110	3,080	3,050 r/	3,100 e/
Refinery 5/ do.	2,870 r/	3,040 r/	3,100 r/	3,300 r/	3,530 e/
Secondary refinery do.	2,760 r/	2,840 r/	2,840 r/	2,830 r/	2,930 e/
Price, London Metal Exchange, cents per pound pure lead, cash average 4/	35.10	28.29	23.96	22.78	20.57

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Domestic ores and base bullion."

1/ Data are rounded to no more than three significant digits, except prices.

2/ Lead recoverable after smelting and refining. Table 14 represents lead in concentrate.

3/ American Bureau of Metal Statistics Inc.

4/ Platt's Metals Week.

5/ Primary metal production only; includes secondary metal production, where inseparable.

TABLE 2
MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY STATE 1/

(Metric tons)

State	1999	2000
Alaska and Missouri	464,000	416,000
Montana	7,950	W
Other States 2/	31,200	41,000
Total	503,000	457,000

W Withheld to avoid disclosing company proprietary data; included with "Other States."

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes Colorado, Idaho, Nevada, New York, and Tennessee.

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TABLE 3
LEADING LEAD-PRODUCING MINES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of lead
1	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Lead-zinc ore.
2	Fletcher	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
3	Brushy Creek	do.	do.	Do.
4	Buick	Iron, MO	do.	Do.
5	Sweetwater	Reynolds, MO	do.	Do.
6	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Silver ore.
7	Viburnum #28	Iron, MO	Doe Run Resources Corp.	Lead ore.
8	Greens Creek 1/	Admiralty Island, AK	Kennecott Greens Creek Mining Co.	Zinc ore.
9	West Fork	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
10	Viburnum #29	Washington, MO	do	Do.
11	Casteel	Iron, MO	do.	Do.
12	Montana Tunnels	Jefferson, MT	Apollo Gold Co.	Zinc ore.
13	Sunshine	Shoshone, ID	Sunshine Mining Co.	Silver ore.
14	Gordonsville	Smith, TN	Pasminco Ltd.	Zinc ore.
15	McCoy/Cove	Lander, NV	Echo Bay Minerals Co.	Gold ore.
16	Galena	Shoshone, ID	Silver Valley Resources Corp.	Silver ore.
17	Balmat	St. Lawrence, NY	Zinc Corp. of America	Zinc ore.
18	Pierrepont	do.	do.	Do.
19	Young	Jefferson, TN	ASARCO Inc.	Do.

1/ Updated to reflect locality name change.

TABLE 4
REFINED LEAD PRODUCED AT PRIMARY REFINERIES IN THE UNITED STATES, BY SOURCE MATERIAL 1/

(Metric tons, unless otherwise specified)

Source material		1999	2000
Refined lead:			
Domestic ores and base bullion		350,000	341,000
Foreign ores and base bullion		W	W
Total		350,000	341,000
Calculated value of primary refined lead 2/	thousand	$337,000	$328,000

W Withheld to avoid disclosing company proprietary data; included with "Domestic ores and base bullion."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Value based on average quoted price.

TABLE 5
LEAD RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons, unless otherwise specified)

		1999	2000
Kind of scrap:			
New scrap:			
Lead-base		42,700	35,500
Copper-base		10,100	11,400
Total		52,800	46,900
Old scrap:			
Battery-lead		1,020,000	1,020,000
All other lead-base		37,100	59,300
Copper-base		7,210	4,730
Total		1,060,000	1,080,000
Grand total		1,110,000	1,130,000
Form of recovery:			
As soft lead		635,000	651,000
In antimonial lead		444,000	428,000
In other lead alloys		18,100	36,800
In copper-base alloys		17,300	16,100
Total		1,110,000	1,130,000
Value 2/	thousands	$1,070,000	$1,090,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Value based on average quoted price of common lead.

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TABLE 6
U.S. CONSUMPTION OF LEAD, BY PRODUCT 1/

(Metric tons)

SIC code	Product	1999	2000
	Metal products:		
3482	Ammunition, shot and bullets	58,300	63,500
	Bearing metals:		
35	Machinery except electrical	W	W
36	Electrical and electronic equipment	W	W
371	Motor vehicles and equipment 2/	1,120	1,090
37	Other transportation equipment	W	W
	Total	1,570	1,480
3351	Brass and bronze, billets and ingots	3,940	3,670
36	Cable covering, power and communication	2,410	W
15	Calking lead, building construction	971	1,140
	Casting metals:		
36	Electrical machinery and equipment	W	W
371	Motor vehicles and equipment	27,600	28,400
37	Other transportation equipment	W	W
3443	Nuclear radiation shielding	1,770	1,270
	Total	34,300	35,100
	Pipes, traps, other extruded products:		
15	Building construction	2,020	2,010
3443	Storage tanks, process vessels, etc.	(3/)	(3/)
	Total	2,020	2,010
	Sheet lead:		
15	Building construction	11,600	17,600
3443	Storage tanks, process vessels, etc.	(3/)	(3/)
3693	Medical radiation shielding	3,890	6,190
	Total	15,400	23,800
	Solder:		
15	Building construction	2,450	1,440
	Metal cans and shipping containers	W	W
367	Electronic components,accessories and other electrical equipment	6,140 r/	5,430
371	Motor vehicles and equipment	W	W
	Total	13,100	11,500
	Storage batteries:		
3691	Storage battery grids, post, etc.	765,000 r/	796,000
3691	Storage battery oxides	707,000 r/	690,000
	Total storage batteries	1,470,000	1,490,000
371	Terne metal, motor vehicles and equipment	(4/)	(4/)
27	Type metal, printing and allied industries	(5/)	(5/)
34	Other metal products 6/	7,130	21,700
	Total	1,610,000	1,650,000
	Other oxides:		
285	Paint	W	W
32	Glass and ceramics products	W	W
28	Other pigments and chemicals	W	W
	Total	58,200	52,400
	Miscellaneous uses	15,100	14,000
	Grand total	1,680,000	1,720,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in appropriate totals.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes "Terne metal, motor vehicles and equipment."
3/ Included with "Building construction" to avoid disclosing company proprietary data.
4/ Included with "Bearing metals, motor vehicles and equipment."
5/ Included with "Other metal products" to avoid disclosing company proprietary data.
6/ Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, electrowinning, and fishing weights.

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TABLE 7
U.S. CONSUMPTION OF LEAD IN 2000, BY STATE 1/ 2/

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California, Oregon, Washington	25,600	25,500	5,010	--	56,200
Florida and Georgia	5,530	1,250	18,800	--	25,600
Illinois	24,700	34,000	16,900	--	75,600
Iowa, Michigan, Missouri	44,800	38,800	18,700	--	102,000
Ohio and Pennsylvania	104,000	45,200	66,800	1,270	217,000
Arkansas and Texas	37,200	19,900	16,100	--	73,100
Alabama, Louisiana, Mississippi, Oklahoma	9,930	2,380	--	--	12,300
Colorado, Indiana, Kansas, Kentucky, Minnesota, Nebraska, Tennessee, Wisconsin	433,000	110,000	98,100	197	641,000
Connecticut, Delaware, Maine, Maryland, Massachusetts, Montana, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Vermont	29,700	16,600	29,400	--	75,800
Various States	241,000	137,000	61,600	--	439,000
Total	955,000	431,000	331,000	1,460	1,720,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes lead that went directly from scrap to fabricated products.

TABLE 8
U.S. CONSUMPTION OF LEAD IN 2000, BY CLASS OF PRODUCT 1/ 2/

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	60,700	91,300	13,300	1,460	167,000
Storage batteries	832,000	339,000	315,000	--	1,490,000
Other oxides	W	--	--	--	W
Miscellaneous	62,500	312	3,620	--	66,500
Total	955,000	431,000	331,000	1,460	1,720,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes lead that went directly from scrap to fabricated products.

TABLE 9
STOCKS OF LEAD AT CONSUMERS AND SECONDARY SMELTERS
IN THE UNITED STATES, DECEMBER 31 1/

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1999	35,300 r/	24,500 r/	18,700 r/	135	78,700 r/
2000	58,500	30,300	15,400	94	104,000

r/ Revised.
1/ Data are rounded to no more than three significant digits.

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TABLE 10
PRODUCTION AND SHIPMENTS OF LEAD PIGMENTS AND OXIDES IN THE UNITED STATES 1/ 2/

(Metric tons, unless otherwise specified)

	1999				2000			
	Production		Shipments		Production		Shipments	
Product	Gross weight	Lead content	Quantity	Value 3/	Gross weight	Lead content	Quantity	Value 3/
Litharge, red lead and white lead, dry	1,750	1,430	20,800	$17,400,000	1,770	1,450	21,000	$10,800,000
Leady oxide	728,000	692,000	NA	NA	724,000	687,000	NA	NA
Total	730,000	693,000	NA	NA	725,000	689,000	NA	NA

NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes basic lead sulfate to avoid disclosing company proprietary data.
3/ At plant, exclusive of container.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF LEAD PIGMENTS AND COMPOUNDS, BY KIND 1/

Kind	Quantity (metric tons)	Value (thousands)
1999:		
White lead carbonate	1	$11
Red and orange lead	86	664
Chrome yellow, molybdenum orange pigments, lead-zinc chromates	8,470	25,900
Litharge	15,700	9,580
Glass frits (undifferentiated)	13,400	20,000
Total	37,700	56,100
2000:		
White lead carbonate	--	--
Red and orange lead	104	594
Chrome yellow, molybdenum orange pigments, lead-zinc chromates	8,900	26,400
Litharge	18,000	10,600
Glass frits (undifferentiated)	13,300	20,100
Total	40,300	57,600

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 12
U.S. EXPORTS OF LEAD, BY COUNTRY 1/

(Lead content, unless otherwise specified)

	1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates:				
Belgium	31,800	$7,430	49,300	$12,000
Canada	12,600	10,000	11,100	9,190
China	--	--	--	--
Japan	39,400	9,240	32,200	7,530
Korea, Republic of	1,840	905	5,380	3,400
Mexico	7,600	5,670	17,500	9,230
Netherlands	63	41	--	--
United Kingdom	2	5	629	409
Other	165 r/	57 r/	425	885
Total	93,500	33,400	117,000	42,600
Ash and residues:				
Belgium	280	68	536	116
Canada	709	1,640	695	1,890
Japan	--	--	9,820	16,200
United Arab Emirates	321	232	206	122
Other	122	62	64	75
Total	1,430	2,000	11,300	18,400

See footnotes at end of table.

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TABLE 12--Continued
U.S. EXPORTS OF LEAD, BY COUNTRY 1/

(Lead content, unless otherwise specified)

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Base bullion:				
Belgium	422	$475	638	$922
Canada	1,870	6,160	7,840	24,600
Mexico	61,800	69,500	23,600	49,800
Other	19	33	12	15
Total	64,100	76,200	32,100	75,300
Unwrought lead and lead alloys:				
Canada	9,880	6,360	9,070	6,150
France	36	267	--	10
Germany	14	73	68	99
Hong Kong	55	276	33	173
India	69	121	116	208
Israel	43	155	353	766
Japan	55	371	46	333
Korea, Republic of	5,140	3,240	3,190	2,060
Mexico	7,580	5,580	8,150	13,400
Netherlands	39	127	4	25
Thailand	8	35	47	33
United Arab Emirates	146	205	17	29
United Kingdom	56	221	65	80
Other	295 r/	661 r/	220	446
Total	23,400	17,700	21,400	23,800
Wrought lead and lead alloys:				
Argentina	133	502	5	76
Australia	12	57	45	82
Belgium	183	2,190	136	1,660
Canada	5,660	4,230	5,260	4,790
China	131	380	1,320	928
Colombia	27	67	23	71
France	32	396	77	148
Germany	70	1,250	143	1,780
Hong Kong	833	2,500	528	2,470
Israel	14	126	165	456
Korea, Republic of	139	409	245	6,740
Kuwait	59	751	66	861
Malaysia	26	709	17	831
Mexico	2,580	13,300	15,900	22,100
Netherlands	234	388	143	260
Saudi Arabia	434	3,810	787	6,270
Singapore	2,080	2,600	1,000	1,240
South Africa	65	144	84	188
Spain	18	351	26	530
Taiwan	195	541	211	1,400
United Arab Emirates	34	251	3	41
United Kingdom	355	1,100	166	974
Other	553 r/	2,440 r/	826	3,710
Total	13,900	38,500	27,200	57,600
Scrap (gross weight):				
Argentina	--	--	253	418
Canada	110,000	17,000	65,500	9,850
China	3,160	1,070	2,770	1,140
Dominican Republic	35	206	20	29
France	9	89	131	188
Haiti	36	27	113	66
Hong Kong	186	116	127	76
India	1,200	700	239	237
Japan	258	426	73	55
Korea, Republic of	625	649	328	72
Mexico	146	81	1,640	599
Saudi Arabia	88	144	11	29
Spain	59	55	--	--

See footnotes at end of table.

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TABLE 12--Continued
U.S. EXPORTS OF LEAD, BY COUNTRY 1/

(Lead content, unless otherwise specified)

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Wrought lead and lead alloys--Continued:				
Taiwan	1,610	$918	141	$134
Trinidad and Tobago	33	40	--	--
United Arab Emirates	99	127	--	--
United Kingdom	53	123	75	187
Venezuela	1	9	74	9
Other	204 r/	218 r/	69	125
Total	117,000	22,000	71,600	13,200

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY 1/

(Lead content, unless otherwise specified)

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Ore and concentrates (lead content): 2/				
Australia	87	$81	--	--
Brazil	5,710	907	9,990	$2,280
Canada	(3/)	5	(3/)	25
Mexico	1,580	726	12,600	3,900
Peru	193	60	1,720	306
Poland	2,890	879	4,530	805
South Africa	--	--	2,310	491
Other	1,860 r/	438 r/	--	--
Total	12,300	3,100	31,200	7,810
Base bullion (lead content):				
Colombia	88	38	65	30
Other	2	20	--	--
Total	90	58	65	30
Pigs and bars (lead content):				
Australia	21,900	11,100	36,000	15,700
Belgium	218	505	65	172
Canada	198,000	119,000	216,000	123,000
China	47,700	23,700	72,100	34,800
Colombia	1,960	782	189	78
Germany	1,000	876	537	1,600
Kazakhstan	2,390	1,130	4,160	1,990
Mexico	27,200	13,100	18,400	7,270
Peru	6,930	3,590	1,790	1,040
United Arab Emirates	46	182	30	137
Other	3,840 r/	1,840 r/	7,250	3,720
Total	311,000	175,000	356,000	190,000
Reclaimed scrap, including ash and residues (lead content), United Kingdom 4/	--	--	25	5
Grand total	324,000	179,000	388,000	198,000
Wrought lead, all forms, including wire and powders (gross weight):				
Australia	3,070	1,610	28	129
Belgium	80	54	75	178
Canada	2,690	4,460	2,870	4,960
China	295	963	519	1,130
El Salvador	814	536	803	568
France	32	63	66	292
Germany	501	2,340	895	2,440
Guatemala	1	4	125	86

See footnotes at end of table.

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TABLE 13--Continued
U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY 1/

(Lead content, unless otherwise specified)

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Wrought lead, all forms, including wire and powders (gross weight)--Continued				
Hong Kong	173	$570	118	$412
Italy	260	299	12	71
Japan	79	555	117	943
Mexico	1,110	1,370	415	814
Netherlands	320	1,220	858	2,890
New Zealand	53	495	56	487
Peru	330	257	437	276
Philippines	51	215	10	42
Taiwan	1,300	1,450	1,130	1,340
United Kingdom	441	1,220	476	1,380
Other	235 r/	641 r/	186	855
Total	11,800	18,300	9,200	19,300

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Also includes other lead-bearing materials containing more than 5 troy ounces per short ton of gold or more than 100 troy ounces per short ton of total precious metals.
3/ Less than 1/2 unit.
4/ Also includes other lead-bearing materials containing more than 10% by weight of copper, lead, or zinc (any one).

Source: U.S. Census Bureau.

TABLE 14
LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria	1,016	845 r/	3,467 r/	5,801 r/	6,215 3/
Argentina	11,272	13,760	15,004	14,256 r/	15,000
Australia	522,000	531,000	618,000	681,000	699,000
Bolivia	16,538	18,608	13,848	10,153 r/	10,100
Bosnia and Herzegovina e/	200	200	200	200	200
Brazil	13,157	14,258	12,394 r/	16,319 r/	16,400
Bulgaria	28,000	32,000	25,000	18,000	15,000
Burma e/	2,200	1,900	2,200	2,000	2,000
Canada	257,253	186,234	189,752	155,369 r/	143,049 p/ 3/
Chile	1,374	1,264	337	170	180
China e/	643,000	712,000	580,000	549,000 r/	570,000
Colombia e/	300	300	300	300	300
Ecuador e/	200	200	200	200	200
Georgia e/	200	200	200	200	200
Greece	8,400	19,300	18,000 e/	16,000 e/	14,000
Honduras	4,700	5,900	4,329	5,226	5,100 p/
India	35,000	32,000	39,300	32,100 r/	28,900
Iran e/ 4/	15,700	18,200 3/	11,000 r/	11,000 r/	15,000
Ireland	45,344	45,149	46,000 e/	45,000 e/	58,600
Italy	11,100	11,792	6,800 e/	6,000 e/	2,000
Japan	7,753	5,227	6,198	6,074	8,835 3/
Kazakhstan e/	35,000	31,000	30,000 3/	34,100	40,000
Kenya e/	5	5	--	--	--
Korea, North e/	80,000	75,000	70,000	70,000	70,000
Korea, Republic of	5,131	3,632	3,558 r/	1,822 r/	1,500
Macedonia	27,000	28,000	26,000	26,000 e/	25,000
Mexico	173,831	174,661	166,060	125,656 r/	156,000
Morocco	71,667	77,056	79,300 r/	79,798 r/	79,800
Namibia	15,349	13,577	13,568 r/	9,361 r/	12,900

See footnotes at end of table.

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TABLE 14--Continued
LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Norway e/	2,083 3/	2,000	-- r/	--	--
Peru	248,787	258,188	259,710	271,782 r/	270,576 p/ 3/
Poland	58,700	55,000	60,000	61,000	60,000
Romania	18,712	17,000	15,000	20,484	20,000
Russia	23,000	16,000	13,000	13,000	13,300
Serbia and Montenegro	10,000	11,000	12,000 e/	3,200 r/ e/	9,000
South Africa	88,613	83,114	84,128	80,191	75,262 3/
Spain	23,826	23,900	18,800	15,000 r/ e/	51,000
Sweden	98,800	108,600	114,430	116,300 r/	108,000 3/
Tajikistan e/	800	800	800	800	800
Thailand	21,000	5,400 r/	6,700 r/	11,900 r/	12,000 3/
Tunisia	4,764	1,424	4,274	6,599 r/	6,602 3/
Turkey	10,971	13,113	13,500 e/	12,000 e/	12,000
United Kingdom e/	1,800	1,800	1,600	1,000	1,000
United States	436,000	459,000	493,000	520,000	468,000 3/
Uzbekistan e/	10,000	-- 5/	-- 5/	-- 5/	-- 5/
Total	3,090,000	3,110,000	3,080,000	3,050,000 r/	3,100,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ In addition to the countries listed, lead is also produced in Nigeria, but information is inadequate to estimate output. Table includes data available through June 29, 2001.
3/ Reported figure.
4/ Year beginning March 21 of that stated.
5/ Mining operations appear to have been sharply curtailed or to have ceased.

TABLE 15
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country	1996	1997	1998	1999	2000 e/
Algeria:					
Primary e/	900	900	900	900	900
Secondary	7,700	7,100	6,100	6,100 e/	6,100
Total	8,600	8,000	7,000	7,000 e/	7,000
Argentina:					
Primary	396	3,282	300 e/	495 r/ e/	8,700
Secondary	27,705	28,834	30,057	25,200 r/ e/	21,000
Total	28,101	32,116	30,357	25,695 r/	29,700
Australia:					
Primary	204,000	204,000	173,000	240,000	223,366 3/
Secondary	24,000	34,000	33,000 r/	32,828 r/	28,430 3/
Total	228,000	238,000	206,000 r/	272,828 r/	251,796 3/
Austria, secondary	22,000 e/	22,700 r/	23,100 r/	24,000 e/	24,000
Belgium:					
Primary	94,400 e/	84,400	74,300 r/	82,900 r/	98,000
Secondary	31,000 e/	26,400	17,200 r/	20,300 r/	20,000
Total	125,000 e/	110,800	91,500 r/	103,200 r/	118,000
Brazil, secondary	45,000	44,500	45,000 e/	45,000 e/	45,000
Bulgaria:					
Primary e/	64,700	62,600	63,000	60,000	60,000
Secondary e/	10,000	10,000	10,000	13,000	10,000
Total	74,670	72,580	72,975	73,000	70,000
Burma, primary	1,984	1,760	1,936	1,666	1,100
Canada:					
Primary	194,031	139,736	129,750	145,889	156,954 p/ 3/
Secondary	115,348	131,659	135,737	117,023	125,898 p/ 3/
Total	309,379	271,395	265,487	262,912	282,852 p/ 3/
China: e/					
Primary	562,000	584,000	665,000	821,000 r/	930,000
Secondary	144,000	123,000	92,000	97,000 r/	100,000
Total	706,000	707,000	757,000	918,000 r/	1,030,000

See footnotes at end of table.

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TABLE 15--Continued
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country	1996	1997	1998	1999	2000 e/
Colombia, secondary	10,000	10,000	12,000	12,000 e/	12,000
Czech Republic, secondary e/	15,000	15,000	15,000	15,000	15,000
France:					
Primary	140,750	131,480	146,000 r/	124,000 r/	100,000
Secondary	162,000	170,820	172,000 r/	155,000 r/	158,000
Total	302,750	302,300	318,000 r/	279,000 r/	258,000
Germany:					
Primary	88,700	164,800	176,800 r/	169,557 r/	210,000
Secondary	149,400	164,400	203,400 r/	204,000 r/	205,000
Total	238,100	329,200	380,200 r/	373,557 r/	415,000
India: e/					
Primary	67,000	69,000	70,000	72,000	70,000
Secondary	27,000	24,000	25,000	20,000	26,000
Total	94,000	93,000	95,000	92,000	96,000
Iran:					
Primary e/	7,000	8,400	9,000	9,000	9,000
Secondary	39,900	41,000	38,000	38,000 e/	38,000
Total	46,900	49,400	47,000	47,000 e/	47,000
Ireland, secondary e/	10,000	10,000	11,000	12,000	12,000
Israel, secondary	12,000	12,000	12,000	13,000	13,000
Italy:					
Primary	65,900	65,700	57,400 r/	66,954 r/	75,000
Secondary	143,900	145,900	141,900 r/	148,354 r/	160,000
Total	209,800	211,600	199,300 r/	215,308 r/	235,000
Jamaica, secondary e/	800	800	800	800	800
Japan:					
Primary	140,531	142,326	144,542	125,514	129,969 3/
Secondary	146,842	154,438	157,555	167,915 r/	182,142 3/
Total	287,373	296,764	302,097	293,429 r/	312,111 3/
Kazakhstan, primary and secondary	70,000 e/	81,974	118,632	160,000 e/	210,000
Korea, North: e/					
Primary	75,000	75,000	75,000	70,000	70,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	80,000	80,000	80,000	75,000	75,000
Korea, Republic of:					
Primary	88,556	121,296	133,066	140,317	170,704 3/
Secondary e/	10,000	10,000	10,000	10,000	10,000
Total e/	98,600	131,000	143,000	150,000	181,000
Macedonia:					
Primary	23,000 r/	24,046 r/	26,000 r/	19,000 r/ e/	19,000
Secondary e/	600 r/	2,000	2,415 r/ 3/	738 r/	1,000
Total e/	23,600 r/	26,000 r/	28,415 r/ 3/	19,700 r/	20,000
Malaysia, secondary e/	36,000	42,000	35,000 r/	35,000 r/	35,000
Mexico:					
Primary 4/	150,395	168,164	163,206	111,136 r/	150,000
Secondary e/	10,000	10,000	10,000	10,000	10,000
Total e/	160,000	178,000	173,000	121,000 r/	160,000
Morocco:					
Primary	59,749	64,202	59,000	57,000 e/	57,000
Secondary	3,100	3,000	3,000	3,000 e/	3,000
Total	62,849	67,202	62,000	60,000 e/	60,000
Namibia, primary 5/	8,588	1,530	236	--	--
Netherlands, secondary	22,000	19,500	13,200	19,900 r/	20,000
New Zealand, secondary e/	6,000	6,000	6,000	6,000	10,000
Nigeria, secondary e/	4,000	4,000	5,000	5,000	5,000
Pakistan, secondary e/	2,000	2,000	2,000	2,000	2,000
Peru, primary	94,324	97,882 r/	109,492	111,276	116,412 p/ 3/
Philippines, secondary e/	17,200	17,000	17,000	12,389 r/ 3/	16,218 3/
Poland: e/					
Primary	51,000	49,900	49,300	50,000	35,412 3/
Secondary	15,000	15,000	15,000	13,985 r/ 3/	10,000
Total	66,000 3/	64,900	64,300	64,000 r/	45,400
Portugal, secondary e/	5,900	6,000	6,000	6,000 r/	6,000

See footnotes at end of table.

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TABLE 15--Continued
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country	1996	1997	1998	1999	2000 e/
Romania: e/					
Primary	20,000 3/	18,000	20,000	15,000 r/	15,000
Secondary	4,000	4,000	4,000	2,500 r/	2,500
Total	24,000	22,000	24,000	17,500 r/	17,500
Russia, primary and secondary e/	30,000	52,000	36,000	62,000 r/	59,000
Serbia and Montenegro, primary	30,317	23,632	23,756 r/	3,690 r/	1,242 3/
Slovenia, secondary	7,237	14,500 r/	14,000 r/ e/	14,000 r/ e/	15,300
South Africa, secondary	32,200	41,500	39,200	40,000 e/	40,000
Spain, secondary e/	86,000	74,900	90,000 r/	96,000 r/ 3/	120,000
Sweden:					
Primary	42,200	34,700	40,600 e/	38,000 r/ e/	37,800
Secondary	41,900	51,500	52,000 e/	48,000 r/ e/	45,000
Total	84,100	86,200	92,600 e/	86,000 r/ e/	82,800
Switzerland, secondary e/	6,200	6,000	7,600	7,000	8,000
Thailand, secondary	12,789	14,968	18,906	23,741	24,000
Trinidad and Tobago, secondary e/	1,600	1,600	1,600	1,600	1,600
Turkey: e/					
Primary	4,000	7,000	8,000	4,000	4,000
Secondary	2,000	2,000	4,000	4,000	2,000
Total	6,000	9,000	12,000	8,000	6,000
Ukraine, secondary e/	21,000	11,000	9,000	9,902 r/ 3/	15,034 3/
United Kingdom:					
Primary	168,108	215,243	186,212 r/	185,422 r/	166,411 3/
Secondary	177,466	175,783	162,651 r/	162,651 r/	170,740 3/
Total	345,574	391,026	348,863 r/	348,073 r/	337,151 3/
United States:					
Primary	326,000	343,000	337,000	350,000	341,000 3/
Secondary	1,070,000	1,110,000	1,120,000	1,110,000	1,130,000 3/
Total	1,400,000	1,450,000	1,450,000	1,460,000	1,470,000 3/
Venezuela, secondary e/	25,000 r/	25,000 r/	25,000 r/	25,000 r/	30,000
Grand total:	5,630,000 r/	5,880,000 r/	5,940,000 r/	6,130,000 r/	6,460,000
Of which:					
Primary	2,770,000 r/	2,910,000 r/	2,940,000 r/	3,070,000 r/	3,260,000
Secondary	2,760,000 r/	2,840,000 r/	2,840,000 r/	2,830,000 r/	2,930,000
Undifferentiated	100,000	134,000	155,000	222,000 r/	269,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 29, 2001. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead but exclude, to the extent possible, simple remelting of scrap.

3/ Reported figure.

4/ Includes lead content in antimonial lead.

5/ Includes products of imported concentrate.

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LIME

By M. Michael Miller

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Lime is an important chemical with numerous chemical, industrial, and environmental uses in the United States. Some evidence of its use as a lime mortar has been found at a site in what is now eastern Turkey dating between 7,000 and 14,000 years ago. More definite evidence of its use in mortars in the Near East and in the former Yugoslavia dates from 8,000 years ago. In Tibet, it was used to stabilize clays in the construction of the pyramids of Shersi 5,000 years ago. The ancient Egyptians used lime as an ingredient in mortar and plaster. The Chinese, Greek, Roman, and other ancient civilizations used lime for construction, agriculture, bleaching, and tanning (Oates, 1998, p. 3-4). Its uses began expanding with the advent of the industrial revolution, but it remained primarily a construction commodity until the rapid growth of the chemical process industries at the beginning of the 20th century. At the turn of the 20th century, more than 80% of the lime consumed in the United States was used in construction, but currently more than 90% is used in chemical and industrial applications.

The term "lime" as used throughout this chapter refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. There are two high-calcium forms—high-calcium quicklime (calcium oxide, CaO) and high-calcium hydrated lime [calcium hydroxide, $Ca(OH)_2$]. There are four dolomitic forms—dolomitic quicklime ($CaO \cdot MgO$), dolomitic hydrate type N [$Ca(OH)_2 \cdot MgO$] and dolomitic hydrate type S [$Ca(OH)_2 \cdot Mg(OH)_2$], and refractory dead-burned dolomite. Lime also can be produced from a variety of calcareous materials, such as aragonite, chalk, coral, marble, and shell. It also is regenerated (produced as a byproduct) by paper mills, carbide plants, and water-treatment plants. Regenerated lime, however, is beyond the scope of this report.

Production

Lime is a basic chemical that was produced as quicklime at 101 plants in 33 States and Puerto Rico (table 2). Hydrated lime was produced at 12 separate hydrating facilities (including 1 plant where the kiln has been shut down but hydrate was manufactured from quicklime produced offsite). In four States with no quicklime production, hydrating plants used quicklime shipped in from other States. There were also a small number of slurry plants, where lime was converted to liquid form prior to sale. Principal producing States were, in descending order of production, Missouri, Kentucky, Alabama, Ohio, Texas, and Pennsylvania.

Domestic production data for lime are derived by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations. The survey is sent to primary producers of quicklime and hydrate but not to independent hydrators that purchase quicklime for hydration so as to avoid double counting. Quantity data are collected for 28 specific and general end uses, and value data are collected by type of lime, such as high calcium or dolomitic. Because value data are not collected by end use, value data shown in table 4 are determined by calculating the average value per metric ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime that the respondent reported sold or used for each end use. The table lists the total quantity sold or used for an end use and the total value of the quicklime and hydrate sold or used for that end use calculated as described above. The same methodology is used to calculate the value of hydrate sold and used in table 5.

The USGS maintains a list of operations classified as producing or idle; in 2000, there were 112 operations listed. One of these operations is not surveyed at the producer's

Lime in the 20th Century

In 1900, U.S. lime production was about 1.8 million metric tons. Historically, lime has always been a very versatile chemical, but when the first survey of lime usage was performed in 1906, nearly 83% of lime was used in building trades for mortar, plaster, and sand-lime brick. The remaining was used in agriculture (9%) and for various chemical and industrial uses (8%). Pennsylvania and Ohio accounted for more than 30% of production. There were more than 1,000 lime burners operating nationwide at the time, and most used vertical shaft kilns producing a few hundred to a few thousand tons per year. The largest lime plants only produced about 20,000 tons per year.

In 2000, the United States produced nearly 19.6 million metric tons of lime. Changes in technologies, new environmental laws, and entirely new uses have resulted in great changes in how lime is consumed. More than 83% of lime was used in descending order, for steelmaking, flue gas desulfurization, water treatment (acid mine drainage, drinking water, and waste water), nonferrous metallurgy, soil stabilization, precipitated calcium carbonate production, sugar refining, and pulp and paper manufacturing. Only about 2% of lime was consumed in traditional building trades. The two leading producing States were Missouri and Kentucky, which accounted for 21% of production. The basic lime manufacturing process had not changed; it still involved heating limestone to dissociate calcium oxide and carbon dioxide. In the past 100 years, kilns have become much larger and use computer monitoring and control systems to operate at high efficiencies. In 2000, more than 10 times as much lime was produced as in 1900, but it was produced at only 107 plants, some of which had production capacities of more than 1 million tons per year.

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request, and estimates are made by using reported prior-year production figures or other industry data. Five of the listed operations were idle in 2000. Of the 108 operations to which the 2000 annual survey request was sent, 107 were in operation all or part of the year and 96 responded to the survey, representing 98% of the total sold or used by producers. Production data for the 12 nonrespondents were estimated based on prior-year production figures and other commodity data.

Total lime sold or used by domestic producers in 2000 decreased by about 100,000 metric tons (t) (110,000 short tons) to 19.6 million metric tons (Mt) (21.6 million short tons) from the revised 1999 total of 19.7 Mt (21.7 million short tons) (table 1). Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at $1.19 billion. Commercial sales increased by 165,000 t (182,000 short tons) to 17.5 Mt (19.3 million short tons), while captive consumption decreased by 282,000 t (311,000 short tons) to 2.04 Mt (2.25 million short tons).

The most significant factor affecting the lime industry in 2000 was the impact of high natural gas prices on lime kiln operations. Because of the large increase in natural gas prices, some of the kilns burning these fuels were shut down. Fuel price increases affected mainly plants with vertical shaft and Calcimatic kilns. The commercial lime industry operates a relatively small number of these kilns, but production costs at those plants that do would have risen dramatically. Commercial plants or individual kilns in Missouri, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia were shut down. Kilns in Arizona and Ohio also may have been affected. Since the peak demand season for natural gas is the winter, gas prices were expected to decrease in the spring of 2001, although industry experts still expected prices to be significantly higher than the average price in 1998 and 1999.

The largest commercial lime company in North America, Carmeuse North America, underwent an internal reorganization into central, northern, and southern regions. Plants in Illinois, Indiana, Kentucky, and Pennsylvania were allocated to the central region, plants in eastern Canada, Michigan, and Ohio to the northern region, and plants in Alabama, Louisiana, and Texas to the southern region (William S. Brown, Executive Vice President Marketing and Development, Carmeuse North America, written commun., January 19, 2001).

Graymont Ltd., the Canadian parent company of Continental Lime Inc. and others, reorganized and renamed its lime subsidiaries into the following: Graymont Western US Inc., Graymont Western Canada Inc., Graymont Dolime (OH) Inc., Graymont (PA) Inc., Graymont (QC) Inc., and Graymont (NB) Inc. Graymont produces lime in six U.S. States and five Canadian Provinces (Graymont Ltd., 2000, Related companies, accessed July 11, 2000, at URL http://www.graymont.com/related.htm).

United States Lime & Minerals, Inc. (U.S. Lime & Minerals) started up its new preheater rotary kiln on October 22 at its Arkansas Lime Co. subsidiary in Batesville, AR. The new kiln successfully achieved design volumes in excess of 540 metric tons per day (t/d) (600 short tons per day). U.S. Lime & Minerals is proceeding with financing plans for the construction of phase II of the Arkansas Lime project. The requisite permits for the installation of the phase II kiln have already been obtained, and the company expected to commence construction of phase II in midyear 2001, subject to market demand, the ability to secure competitive bids, and the availability of financing (United States Lime & Minerals, Inc., October 21, 2000, United States Lime & Minerals, Inc. announces results for the third quarter 2000, the start-up of its new kiln in Arkansas, and proposed financings, accessed April 19, 2001, via URL http://www.uslm.com/news.htm).

Chemical Lime Co. and Martin Marietta Materials, Inc., signed an agreement whereby Martin Marietta would process aggregate materials and provide certain operating services at Chemical Lime's lime plant in New Braunfels, TX. Under the agreement, Martin Marietta will build an aggregates plant to process what is currently unusable limestone for the lime plant. The plant is expected to be operational the second half of 2001 and will have an initial capacity of about 1.3 to 1.8 million metric tons per year (1.5 to 2.0 million short tons per year). Martin Marietta will also assume responsibility for all pit operations, including supplying kiln feed to the lime plant (Martin Marietta Materials, Inc., July 17, 2000, Martin Marietta Materials, Inc. announces agreement with Chemical Lime Co. in Texas, accessed September 25, 2000, at URL http://www.martinmarietta.com/corpsite/news/press_releases/00_07_17.asp). Chemical Lime's Ten Mile plant located near Bancroft, ID, shut down in late 1999 and was idle all of 2000. The facility was used as a terminal in 2000 for sales of lime produced at other Chemical Lime plants in the region.

Baker Refractories and Wülfrath Refractories GmbH, the refractories arm of the Lhoist Group of Belgium, signed an agreement to merge pending approval by antitrust authorities in Europe and the United States. The new unit will operate under a unifying name and will be headquartered in Hilden, Germany. Baker Refractories manufactures dead-burned refractory-dolomite products in York, PA, and also has manufacturing facilities in the United Kingdom and joint-venture operations in Mexico and Taiwan (Industrial Minerals, 2000).

In the captive lime sector, three plants closed permanently. The Dow Chemical Co.'s lime plant at Ludington, MI, closed in late 1999, when Dow switched to purchasing lime on the open market. Holly Sugar Co.'s sugar beet plants and their respective lime kilns located at Tracy and Woodlands, CA, closed in late 2000.

Of the 43 companies manufacturing quicklime at the end of 2000, 26 were primarily commercial producers, 13 were predominantly captive producers, and 4 combined commercial sales with captive production. During 2000, the 26 commercial producers operated 63 lime plants producing quicklime and 7 separate hydrating plants (including 1 lime plant that was idle but operated its hydrator). The 13 captive producers operated 34 plants producing quicklime primarily for internal company use. At yearend, the top 10 companies were, in descending order of production, (1) Carmeuse North America, (2) Chemical Lime, (3) Graymont Ltd., (4) Mississippi Lime Co., (5) Global Stone Corp., (6) Martin Marietta Magnesia Specialties, Inc., (7) U.S. Lime & Minerals, (8) Vulcan Materials Co., (9) LTV Steel Co., Inc., and (10) Austin White Lime Co. These companies operated 45 lime plants and 6 separate hydrating plants and accounted for 86% of the combined commercial sales of quicklime and hydrated lime and 79% of total lime production.

Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance multiplied by the average 24-hour capacity of quicklime production, including quicklime converted to hydrated lime. In 2000, based on capacity data from 48 commercial plants, the U.S. lime industry

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operated at about 79% of capacity compared with 76% in 1999. The calculations do not include combined commercial and captive producers, hydrating plants, and Puerto Rico.

Environment

The most common fuel used to produce lime in the United States is coal. Emissions generated in the combustion of coal and other fuels make the lime industry subject to regulation under the Clean Air Act. Of immediate concern to the lime industry are the costs and obligations expected for additional monitoring, reporting, and control of particulate matter and hazardous air pollutants such as hydrogen chloride. Of longterm concern, with a potentially greater impact, is the international debate on the reduction of greenhouse gas emissions, particularly carbon dioxide. Lime production generates carbon dioxide from the combustion of fuels and from the calcination process, which dissociates calcium carbonate into calcium oxide and carbon dioxide. Any program to regulate carbon dioxide emissions would affect lime producers.

Consumption

The breakdown of consumption by major end uses (table 4) was as follows: 38% for metallurgical uses, 26% for environmental uses, 24% for chemical and industrial uses, 11% for construction uses, and 1% for refractory dolomite. Captive lime accounted for about 10% of consumption and was used mainly in the production of steel in basic oxygen furnaces, sugar refining, and magnesia and magnesium production. Almost all data on captive lime consumption, excluding the sugar industry, are withheld to protect company proprietary information. As a result, table 4 lists the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table. Values assigned to specific end uses in table 4 should not be construed as being price specific to that market. The USGS does not collect value data by end use, and the values shown in tables 4 and 5 are derived, in general, from average lime values. The market values shown are simply designed to show the relative value of the market.

In steel refining, quicklime is used as a flux to remove such impurities as phosphorus, silica, and sulfur. Dolomitic lime is often substituted for a fraction of the high-calcium lime to extend refractory life. Dolomitic quicklime is also used as a flux in the manufacture of glass. The steel industry accounted for about 31% of all lime consumed in the United States. Lime consumption by the iron and steel industry was 6.15 Mt (6.78 million short tons), a 2.9% increase compared with that of 1999. This increase is in part explained by the lower usage rate of lime in electric arc furnaces. The trend toward using magnesia to replace some dolomitic lime in the steel furnace appears to have leveled off after making inroads into dolomitic lime sales.

The U.S. steel industry reported strong production during the first and second quarters of 2000, but a slowing economy and increased imports resulted in a decrease in production of more than 10% in the third and fourth quarters. For the year, raw steel production was up by 4.2% (3.1%, basic oxygen process and 5.5%, electric arc process) compared with that in 1999.

In nonferrous metallurgy, lime is used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and to maintain the proper pH in the flotation process. Lime is used to process alumina and magnesia, to extract uranium from gold slimes, to recover nickel by precipitation, and to control the pH of the sodium cyanide solution used to leach gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a level between 10 and 11 to maximize the recovery of precious metals and to prevent the creation of hydrogen cyanide. Lime consumed for these various uses is included in table 4 under the category "Other nonferrous metallurgy."

Lime usage in nonferrous metallurgy (mainly concentration of copper and gold ores, aluminum and bauxite processing, and magnesium production) decreased by 17% in 2000. Previously announced cutbacks and closures by copper producers (including the Continental Mine in Montana) were made more acute by power disruptions and high energy costs. Decreases in copper output and magnesium production were primary causes of the decrease in lime consumption. Recoverable mine production of copper decreased by about 8% (Edelstein, 2001). Magnesium production decreased by 23%; the power and energy problems of the Pacific northwest caused production problems for magnesium producer Northwest Alloys, Inc., and for its aluminum customers (Kramer, 2001).

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Lime is used to recover cyanides in such treatment processes as Cyanisorb, alkaline chlorination, and sulfur dioxide/air.

In the environmental sector, lime is used in the softening and clarification of municipal potable water and to neutralize acid-mine and industrial discharges. In sewage treatment, lime's traditional role is to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. Lime also aids clarification and in destroying harmful bacteria. More recently, the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, reduces odors, pathogens, and putrescibility of the solids. Lime stabilization involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time. Lime consumption for all sludge treatment increased by 29% compared with that in 1999. The sewage sludge market increased by 53%, but the industrial and hazardous waste market decreased by 8%.

In flue gas desulfurization (FGD) systems serving electric utility and industrial plants and incinerators, lime is used to react with sulfur oxides in the flue gas and is used to stabilize the resulting sludge before disposal. In 2000, the FGD market grew by 13%, recouping the 10% decrease in sales reported in 1999. The utility industry increased operating and maintenance budgets, which improved plant reliability and helped eliminate much of the unscheduled downtime experienced by some powerplants in 1999. Probably just as important, after mild temperatures in 1999, temperatures returned to more normal ranges, thus increasing the demand for electricity. In addition, the price of nitrogen oxide (NO_x) emission allowances dropped. One of the large midwestern powerplants was forced to reduce

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its power generation to limit NO_x emissions in 1999 but resumed normal operations in 2000.

Lime is used by the pulp and paper industry in the basic Kraft pulping process where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat and sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse. The byproduct calcium carbonate is recalcined in a lime kiln to recover lime for reuse. The paper industry also uses lime as a coagulant aid in the clarification of plant process water.

The pulp and paper market was adversely affected by the slowdown of the economy and by the trend toward increased recycling of byproduct calcium carbonate into lime by pulp and paper producers. These factors resulted in a 17% decrease in lime consumption.

Lime is used to make precipitated calcium carbonate (PCC), a specialty filler used in premium-quality coated and uncoated papers, paint, and plastics. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide is bubbled through milk-of-lime, a suspension of hydrated lime in water, to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals. Lime use for PCC production was unchanged compared with that of 1999.

Lime is used, generally in conjunction with soda ash, for softening plant process water. This precipitation process removes bivalent soluble calcium and magnesium cations (and, to a lesser extent, ferrous iron, manganese, strontium, and zinc), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

The chemical industry uses lime in the manufacture of alkalies. Quicklime is combined with coke to produce calcium carbide, which is used to make acetylene and calcium cyanide. Lime is used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk-of-lime is used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself is then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide is obtained as a byproduct of lime production.

In construction, hydrated lime and quicklime are used in subgrade stabilization to stabilize fine-grained soils in place of materials that are employed as subbases, such as hydraulic clay fills or otherwise poor-quality clay and silty materials obtained from cuts or borrow pits. Lime also is used in base stabilization, which includes upgrading the strength and consistency properties of aggregates that may be judged unusable or marginal without stabilization. Common applications for lime stabilization included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Highway projects, airport runway expansions, and commercial projects kept the large Texas stabilization market at about the same level as in 1999, but nationwide lime sales for stabilization decreased by 7% compared with the revised 1999 figures.

Although the overall quantities of lime used for soil stabilization are believed to be accurate, the data reported in table 5 may not accurately reflect how much hydrated lime is actually used in soil stabilization. Much of the lime used in soil stabilization is consumed as slurry, which may be manufactured by the lime company at a slurry plant or by the user onsite.

In road paving, hydrated lime is used in hot mix asphalt to act as an antistripping agent. Stripping is generally defined as a loss of adhesion between the aggregate surface and the asphalt cement binder in the presence of moisture. Lime also is used in cold in-place recycling for the rehabilitation of distressed asphalt pavements. Existing asphalt pavement is pulverized by using a milling machine, and a hot lime slurry is added along with asphalt emulsion. The cold recycled mix is placed and compacted by using conventional paving equipment, which produces a smooth base course for the new asphalt surface. In 2000, sales of lime for use in asphalt decreased by nearly 7% compared with the revised 1999 figures.

In the traditional building sector, quicklime is used to make calcium silicate building products, such as sand-lime brick and autoclaved aerated concrete (AAC). AAC offers the advantage of producing building materials that can be cut, drilled, and nailed like wood but with the advantages of a concrete product.

Hydrated lime is used in the traditional building sector where it still is used in plaster, stucco, and mortars to improve durability. The recent growth in this traditional lime market is the result of strong growth in nonresidential building construction (industrial buildings, offices, shopping centers, etc.) where architects have specified the use of the traditional lime building materials. According to preliminary data released by the U.S. Census Bureau, there was a 6.8% increase in the value of nonresidential building construction in 2000; the use of hydrated lime in traditional building uses increased by more than 4%. The use of hydrated lime in traditional building uses has increased by 33% since 1997.

A small amount of hydrated lime (estimated to be less than 2% of total building uses) also is used on the renovation of old structures built with lime-based mortars, which were standard before the development of portland cement-based mortars. Modern portland cement-based mortars are incompatible with old lime mortars.

Dead-burned dolomite, also called refractory lime, is used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Hydrated lime is used to produce silica refractory brick used to line industrial furnaces.

Prices

The average values per ton of lime, rounded to three significant figures, are listed in table 8. The values are reported in dollars per metric ton with accompanying conversions into dollars per short ton. For accuracy, the conversions were made from the unrounded metric value and, as a result, may not be an exact conversion of the rounded values. All value data for lime are reported by type of lime produced—high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite. Emphasis is placed on the average value per ton of lime sold.

In 2000, the average value for all types of lime sold and used was essentially unchanged from the previous year. Although

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there was some upward movement in commercial lime prices on an free on board plant basis (less than 2%), because much of the quicklime is sold through long-term contracts to such large customers as steel mills and utilities, significant price increases cannot be enacted until current contracts expire. In some cases, however, lime companies passed along increased fuel and energy costs in the form of surcharges.

The average value per ton of high-calcium quicklime and high-calcium hydrate sold increased only slightly, but dolomitic quicklime and dolomitic hydrate values per ton of lime sold increased by 7% and 17%, respectively. The increase in price for dolomitic quicklime was partly the result of an increase in the steel producer price index in 2000. Steelmaking is the largest market for dolomitic quicklime, and lime supply contracts are sometimes tied to the steel index. In addition, there is increased use of dolomitic quicklime in higher value specialty products manufactured for the steel markets.

Overall, despite idled capacity, strong competition continued to keep prices down. Figures 1 and 2 show the average sales value per ton of quicklime and hydrate over the past 10 years in actual and constant dollars.

Foreign Trade

The United States exported and imported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined exports of lime (table 6) were 73,200 t (80,700 short tons) valued at $9.96 million, with 69% exported to Canada, 17% exported to Mexico, 9% exported to Argentina, and the remaining 5% going to various other countries. Combined imports of lime (table 7) were 113,000 t (125,000 short tons) value at $13.5 million, with 85% coming from Canada and 14% coming from Mexico.

Data on imports and exports of hydraulic lime may be questionable. There is only one known producer of hydraulic lime in the United States, and with exports averaging about 10,000 to 11,000 metric tons per year (t/yr) in 1999 and 2000, it is likely that what is being classified as hydraulic lime is in fact portland cement (or some other hydraulic cement product). Chemically, hydraulic lime and portland cement are quite similar.

No tariffs are placed on imports of hydraulic lime, quicklime, and slaked lime from countries with normal trade relations (NTR) with the United States. There is a 3% ad valorem tariff on imports of calcined dolomite from NTR countries.

World Review

With the exception of industrialized nations with good data collection, accurate lime data for many countries are frequently difficult to acquire. The variations in quality, types of lime, production technologies, and industries manufacturing lime and the frequent confusion with limestone data make accurate reporting of world lime data (table 9) extremely difficult and certainly incomplete. The following is a brief discussion of acquisitions or new construction in specific countries.

Italy.—Calcestruzzi Calò A has purchased a 200-t/d Cim-Reversy oil-fired kiln from Cimprogetti S.p.A. (World Cement, 2001).

Jamaica.—Rugby Jamaica Lime and Minerals Ltd. successfully commissioned its new 400-t/d lime plant near Clarendon. The plant includes a Cimprogetti Twin-D 85 twin shaft regenerative kiln and will supply lime to the local alumina industry (World Cement, 2001).

Mexico.—Mexico's Grupo Calider S.A. de C.V., a joint-venture partner of the Belgian Lhoist Group, acquired Mexican lime producer Caleras Fernandez S.A. de C.V. Caleras Fernandez, which operates in southwestern Mexico, has a 300,000-t/yr plant near Guadalajara and a 35,000-t/yr hydrating plant near Cimarron (Lhoist Group, July 2000, Acquisition of Mexican Caleras Fernandez, accessed January 5, 2001, at URL http://www.lhoist.com/about/news/intro.html).

Peru.—Cia. De Minas de Buenaventura S.A. de C.V. successfully commissioned its new oil-fired Cimprogetti Cim-Reversy twin shaft regenerative kiln. The 130-t/d kiln is located at the Yanococha Gold Mine (World Cement, 2001).

Poland.—In November 2000, Lhoist Bukowa Sp. zo. o. started up its new 600-t/d Maerz kiln. The new kiln increases the plant's capacity to 1,760 t/d and makes it the most modern lime plant in the Kielce region. Additional work on a new hydrating plant and pebble lime storage facilities are expected to be completed by June 2001 (Lhoist Group, November 2000, New kiln at Lhoist Bukowa, accessed April 30, 2001, at URL http://www.lhoist.com/about/news/intro.html).

Spain.—Caleras De San Cucao has placed an order for a Cimprogetti gas-fired Twin-D 70 kiln. The kiln is designed to alternate between producing high-calcium lime and dolomitic lime (World Cement, 2001). A Maerz lime kiln was installed at Ciarues S.A.'s Aragon plant. The new kiln has a capacity of 200 t/d and is natural-gas/coal-dust fired (World Cement, 2001).

United Kingdom.—On December 14, the Lhoist Group of Belgium acquired the United Kingdom lime business of RMC Group plc. The acquisition includes two Maerz kilns with an annual capacity of 200,000 t/yr near Hindlow, Derbyshire, and a hydrating plant near Hartley, Cumbria. The new entity will operate under the name Lhoist UK Ltd. (Lhoist Group, December 2000, Lhoist purchases RMC lime in the UK, accessed January 5, 2001, at URL http://www.lhoist.com/about/news/intro.html).

Outlook

Lime has dozens of end uses in the chemical, industrial, and construction industries, but sales are dominated, in descending order by tonnage, by the iron and steel markets, FGD, pulp and paper including the related PCC market, construction, and nonferrous metallurgy. These market groups accounted for 75% of total lime consumption in 2000.

In the short term, the slowdown of the economy and the energy crisis in the western United States will have a negative impact on lime sales. The domestic steel industry is plagued by high levels of imports, large inventories, and bankruptcies; the slowing economy will only exacerbate the industry's problems. These factors are expected to cause a decrease in U.S. steel production in 2001, and lime sales for steel could be decline by 5% to 10% in 2001.

In 2000, the FGD market recovered from the problems experienced in 1999, and the future for the lime-based FGD remains promising. Phase II of the Clean Air Act Amendments (CAAA), which went into effect January 1, 2000, remains the driving force behind the growth in this market. The costs of lime-based scrubbers have decreased to about $330 per ton of sulfur dioxide removed (from $440 to $1,000 per ton), and lime scrubbers display favorable economics and efficiencies for the

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smaller units regulated under phase II. Regulations covering emissions from small municipal incinerators and waste-to-energy incinerators also favor the use of lime scrubbers. When phase II went into effect, it was thought that the real boost to lime sales for FGD would be slow in coming because of an excess of emission allowances accumulated during phase I of the CAAA and the low prices for emissions allowances. It was thought that it would likely take until 2005 for the scrubber market to really start seeing the demand increase from the phase II regulation. There has been a steep rise in the price of emissions allowances from about $130 per ton to more than $200 per ton between the fall of 2000 and the spring of 2001. If allowance prices continue to rise or stay at current levels, the economics of installing scrubbers may become more attractive earlier than the previously forecasted 2005 time period.

Analysis of the energy crisis of 2000 and the potential for energy shortages in the future has indicated that the quickest way to expand generating capacity is to maximize the use of existing powerplants and to add capacity at current facilities. There continues to be strong public support for environmental cleanup of emissions, so greater use of FGD controls is likely in the future. The higher prices of natural gas, which has been the preferred fuel for new powerplants, also has made coal a more acceptable option for future power plant construction.

In a recent forecast of air pollution control markets, The McIlvaine Co. predicted that U.S. utilities will spend $25 billion over the next 9 years on flue gas desulfurization. The majority of these systems will use lime or limestone and produce byproduct gypsum. About 60% will be for existing powerplants and 40% for new coal-fired powerplants (The McIlvaine Co., November 2000, Huge U.S. power plant scrubber market now developing, accessed April 30, 2001, at URL http://www.mcilvainecompany.com/news%20releases/NR600.htm).

Increased funding for highway and airport construction as authorized by the Transportation Equity Act for the 21st Century (TEA-21) and the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR-21) should benefit the soil stabilization and asphalt markets over the next several years. The following are two examples of projects that potentially could benefit from the acts. AIR-21 will help fund runway expansion projects that have been announced for Corpus Christi International Airport, Dallas-Fort Worth International Airport, and McAllen-Miller International Airport (located west of Brownsville, TX). In addition, TEA-21 designated the "Ports to Plains" corridor linking Denver, CO, with the Texas-Mexico border as 1 of 43 high-priority corridors. Several transportation studies have been conducted on this corridor in the past, but a major feasibility study is underway that will examine preferred highway alignments and the feasibility of highway improvements. The goal would be to develop a four-lane divided highway linking the two points (Wilbur Smith Associates, January 2001, Ports to plains feasibility study process, accessed May 1, 2001, at URL http://www.wilbursmith.com/portstoplains). If this corridor gets built, it would provide a large potential market for lime stabilization that could last for years.

The traditional building markets (masonry and finishing lime) have shown unexpected growth in recent years and the trend should continue, but with the economy lagging in 2001 the growth rate of nonresidential construction is likely to slow.

Sales to the traditional pulp and paper market have decreased in recent years mainly because of increased recycling of byproduct calcium carbonate. This market will also be adversely affected by the announced closure of three International Paper Co. mills at Mobile, AL, Camden, AR, and Lock Haven, PA, and reduced operations at Courtland, AL (Tappi, October 20, 2000, PACE addresses mill closures, downsizing at IP, accessed November 15, 2000, via URL http://www.tappi.org). These closures will also adversely affect the PCC market because Minerals Technologies, Inc., operates satellite PCC mills at Lock Haven and Mobile, although PCC production at Courtland will be unaffected. On the positive side, Minerals Technologies opened a new merchant PCC mill at Brookhaven, MS, which will manufacture PCC for such nonpaper uses as vinyl siding and automotive and construction sealants (North American Minerals News, 2000b). In addition, Minerals Technologies signed an agreement to construct a satellite PCC mill at a paper mill in Millinocket, ME, owned by Great Northern Paper, Inc. The plant is expected to be in operation in the third quarter of 2001 (North American Minerals News, 2001). Despite the closures by International Paper, which will slow the growth of PCC in 2001, the PCC market should exhibit solid growth in the long term. Its penetration of the groundwood paperboard markets is considered a driver of future PCC demand. Kline & Co., a consultancy based in Fairfield, NJ, expects PCC use in paper and paperboard to grow on average by 6% per year through 2004 (North American Minerals News, 2000a).

The increase in natural gas prices already has had a dramatic effect on lime plant operations. With gas prices expected to remain high and coal prices rising because of increased demand as gas users try to switch fuels, lime plant operating costs will increase. Higher prices for transportation fuels (mainly diesel) will also increase operating costs. If these fuel prices continue at elevated levels, as current long-term contracts expire, lime producers will certainly attempt to raise prices. In the long term, coal prices are expected to come down as coal mine output catches up with demand. Considering the strong competition between lime companies and excess production capacity, the biggest impact of the current energy problems on the lime industry likely will not be big price increases but rather more production from coal-fired kilns. Companies will, where possible, convert gas-fired kilns to coal firing, but it is not known if this is feasible for all types of kilns.

References Cited

Edelstein, D.L., 2001, Copper in December 2000: U.S. Geological Survey Mineral Industry Surveys, March, 10 p.

Industrial Minerals, 2000, Refractory dolomite consolidation—Lhoist/Wülfrath to merge with Baker Refractories: Industrial Minerals, no. 397, October, p. 8-9.

Kramer, D.A., 2001, Magnesium in the fourth quarter 2000: U.S. Geological Survey Mineral Industry Surveys, February, 4 p.

North American Minerals News, 2000a, Kline predicts pigment growth to outpace paper production: North American Minerals News, no. 67, December, p. 16.

———2000b, MTI dedicates Brookhaven PCC plant—Expansion likely: North American Minerals News, no. 66, November, p. 4.

———2001, MTI to build PCC plant in Maine: North American Minerals News, no. 69, February, p. 3.

Oates, J.A.H., 1998, Lime and limestone—Chemistry and technology, production and uses: Weinem, Germany, Wiley–VCH, 455 p.

World Cement, 2001, World lime review: World Cement, v. 32, no. 4, April, p. 52-56.

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Lime. Ch. in Mineral Commodity Summaries, annual.
Lime. Ch. in Minerals Yearbook, annual.
Limestone and Dolomite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Chemical Economics Handbook. SRI International.
Chemical Market Reporter.
Chemistry and Technology of Lime and Limestone. John Wiley & Sons, 1980.
Industrial Minerals (London).
Industrial Minerals and Rocks. AIME, 6th ed., 1994.
Industrial Specialty News.
Lime. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Lime and Limestone: Chemistry and Technology, Production and Uses. Wiley—VCH, 1998.
Lime Facts. National Lime Association, 1999.
North American Minerals.

TABLE 1
SALIENT LIME STATISTICS 1/

(Thousand metric tons, unless otherwise specified) 2/

	1996	1997	1998	1999	2000
United States: 3/					
Number of plants	108	106	107	108	107
Sold or used by producers:					
High-calcium quicklime	NA	14,300	14,800	14,100	14,800
Dolomitic quicklime	NA	2,900	2,740	3,000 r/	2,570
Total	16,800	17,300	17,500	17,100	17,300
High-calcium hydrated lime	NA	1,820	1,950	2,010 r/	1,550
Dolomitic hydrated lime	NA	352	383	298	421
Total	2,190	2,170	2,330 r/	2,310 r/	1,970
Dead-burned dolomite 4/	300	300	300	300	200
Grand total	19,200	19,700	20,100	19,700 r/	19,600
Value 5/ thousands	$1,150,000 r/	$1,200,000	$1,250,000 r/	$1,190,000 r/	$1,190,000
Average value per ton	$61.50	$61.00	$60.40	$60.40 r/	$60.60
Lime sold	16,800	17,300	17,800	17,400 r/	17,500
Lime used	2,440 r/	2,420	2,320 r/	2,320 r/	2,040
Exports: 6/					
Quantity	68 7/	80	56	59	73
Value thousands	$8,810 7/	$9,550	$9,110	$8,270 r/	$9,960
Imports for consumption: 6/					
Quantity	298 7/	276 r/	231	140 r/	113
Value thousands	$27,500 7/	$26,500	$22,700	$15,700 r/	$13,500
Consumption, apparent 8/	19,400	19,900	20,300	19,800 r/	19,600
World, production	114,000 r/	116,000 r/	116,000 r/	116,000 r/	116,000 e/

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Excludes regenerated lime.
4/ Data rounded to no more than one significant digit to protect company proprietary data.
5/ Selling value, f.o.b. plant, excluding cost of containers.
6/ U.S. Census Bureau.
7/ The 1996 data were revised to correlate with the data for following years.
8/ Defined as sold or used plus imports minus exports.

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TABLE 2
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1999 Plants	1999 Hydrated (thousand metric tons)	1999 Quicklime 3/ (thousand metric tons)	1999 Total (thousand metric tons)	1999 Value (thousands)	2000 Plants	2000 Hydrated (thousand metric tons)	2000 Quicklime 3/ (thousand metric tons)	2000 Total (thousand metric tons)	2000 Value (thousands)
Alabama	5	102	1,830	1,930	$114,000	5	111	1,840	1,950	$121,000
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming	20	271	2,320 r/	2,590 r/	151,000 r/	20	273	2,480	2,750	161,000
California, Oregon, Washington	10	64	505	569	47,000	10	54	490	544	38,800
Illinois, Indiana, Missouri	9	329	3,770	4,100	234,000 r/	9	316	3,570	3,890	224,000
Iowa, Nebraska, South Dakota	4	W	W	260	17,500	4	W	W	254	16,600
Kentucky, Tennessee, West Virginia	5	132	2,170	2,300	124,000	5	117	2,400	2,510	139,000
Michigan	8	1	781	781	43,900	7	W	W	530	31,300
Ohio	8	W	W	1,820	105,000	8	121	1,730	1,850	106,000
Pennsylvania	7	176	1,170	1,340	94,300	7	W	W	1,350	93,900
Texas	7	585 r/	1,080	1,670 r/	111,000 r/	7	316	1,280	1,600	105,000
Virginia	5	135	672	807	48,400	5	121	601	722	44,800
Wisconsin	4	149	469	618	37,000	4	150	469	619	37,000
Other 4/	16	173 r/	722 r/	895 r/	58,000 r/	16	164	828	992	68,100
Total	108	2,310 r/	17,400	19,700 r/	1,190,000 r/	107	1,970	17,600	19,600	1,190,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Excludes regenerated lime.

2/ Data are rounded to no more than three significant digits; may not add to totals shown.

3/ Includes dead-burned dolomite.

4/ Includes Arkansas, Georgia, Louisiana, Massachusetts, Minnesota, North Dakota, Oklahoma, Puerto Rico, South Carolina, and data indicated by the symbol W.

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TABLE 3
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY RANGE OF PRODUCTION 1/ 2/

Range of production	1999 Plants	1999 Quantity r/ (thousand metric tons)	1999 Percent of total	2000 Plants	2000 Quantity (thousand metric tons)	2000 Percent of total
Less than 25,000 tons	25 r/	404	2	22	351	2
25,000 to 100,000 tons	25 r/	1,350	7	28	1,480	8
100,000 to 200,000 tons	24 r/	3,510	18 r/	24	3,370	17
200,000 to 300,000 tons	15 r/	3,580	18 r/	14	3,390	17
300,000 to 400,000 tons	7 r/	2,330	12 r/	6	2,040	10
400,000 to 600,000 tons	5 r/	2,550	13 r/	7	3,530	18
More than 600,000 tons	7 r/	5,950	30 r/	6	5,400	28
Total	108	19,700	100	107	19,600	100

r/ Revised.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1999 Quantity 4/	1999 Value	2000 Quantity 4/	2000 Value
Chemical and industrial:				
Fertilizer (aglime and fertilizer)	23	1,900	48	3,540
Glass	98	5,650	84	5,060
Paper and pulp	971	57,800 r/	802	48,400
Precipitated calcium carbonate	1,200	71,100	1,200	72,900
Sugar refining	792 r/	46,400 r/	867	53,000
Other chemical and industrial	1,920	122,000 r/	1,670	110,000
Total	5,010 r/	305,000 r/	4,670	293,000
Metallurgical:				
Steel and iron:				
Basic oxygen furnaces	3,860 r/	219,000 r/	4,000	229,000
Electric arc furnaces	1,870 r/	111,000 r/	1,840	111,000
Other steel and iron	239	14,700	300	17,900
Total	5,970	344,000 r/	6,150	358,000
Nonferrous metals:				
Aluminum and bauxite	242 r/	14,600 r/	W	W
Other nonferrous metallurgy 5/	1,330 r/	76,400 r/	W	W
Total nonferrous metals	1,570	91,000	1,310	66,300
Total metallurgical	7,550	435,000 r/	7,450	424,000
Construction:				
Asphalt	370 r/	27,100 r/	345	27,300
Building uses	396	40,400	437	43,900
Soil stabilization	1,370 r/	89,200 r/	1,270	80,500
Other construction	31 r/	2,130 r/	14	1,350
Total	2,170 r/	159,000 r/	2,070	153,000
Environmental:				
Flue gas sulfur removal:				
Utility powerplants	2,650 r/	135,000 r/	2,990	158,000
Incinerator	140 r/	8,910 r/	139	9,020
Other	34	2,110 r/	31	2,120
Total	2,820 r/	146,000 r/	3,160	169,000
Sludge treatment:				
Sewage	147	9,890 r/	225	14,100
Other (industrial, hazardous, etc.)	98	6,720 r/	90	5,690
Total	245	16,600 r/	316	19,800
Water treatment:				
Acid mine drainage	91 r/	5,940 r/	103	6,650
Drinking water	904	56,000	958	59,600
Waste water	433 r/	28,100 r/	424	28,300
Total	1,430 r/	90,000 r/	1,480	94,600

See footnotes at end of table.

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TABLE 4--Continued
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1999		2000	
	Quantity 4/	Value	Quantity 4/	Value
Environmental--Continued:				
Other environmental	178 r/	11,700 r/	155	10,700
Total environmental	4,690	265,000	5,120	294,000
Refractories (dead-burned dolomite)	300 6/	21,800 r/ 7/	200 6/	21,900 7/
Grand total	19,700 r/	1,190,000 r/	19,600	1,190,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ To convert metric tons to short tons, multiply metric tons by 1.10231.
4/ Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for copper ore concentration, magnesia, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, mason's lime, and refractories.
5/ Includes ore concentration (copper, gold, etc.), magnesium, and other.
6/ Data rounded to one significant digit to protect company proprietary data.
7/ Values are estimated based on average value per ton for 1999 and 2000.

TABLE 5
HYDRATED LIME SOLD OR USED IN THE UNITED STATES, BY END USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1999		2000	
	Quantity 4/	Value	Quantity 4/	Value
Chemical and industrial	477 r/	38,000 r/	431	37,000
Construction:				
Asphalt paving	356 r/	26,500 r/	325	26,200
Building uses	394	40,200	411	42,300
Soil stabilization	528 r/	39,400 r/	237	17,600
Other construction	16	1,080	10	1,140
Total	1,290 r/	107,000 r/	983	87,200
Environmental:				
Flue gas treatment (FGT):				
Incinerators	19 r/	1,380 r/	25	1,860
Industrial boilers and other FGT	19 r/	1,280 r/	37	2,730
Utility powerplants	42 r/	2,790 r/	47	3,490
Total	80 r/	5,460 r/	109	8,080
Sludge treatment:				
Sewage	17 r/	1,420 r/	28	2,280
Other sludge treatment	21 r/	1,760 r/	17	1,470
Total	38 r/	3,180 r/	45	3,750
Water treatment:				
Acid mine drainage	55 r/	3,620 r/	54	3,620
Drinking water	199	15,200	143	11,900
Wastewater	114 r/	8,240 r/	150	11,300
Total	368 r/	27,000 r/	347	26,800
Other environmental	31 r/	2,670 r/	33	2,580
Metallurgy	22	1,560 r/	19	1,650
Grand total	2,310 r/	185,000 r/	1,970	167,000

r/ Revised.
1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ To convert metric tons to short tons, multiply metric tons by 1.10231.
4/ Quantity includes hydrated lime sold or used, where "used" denotes lime produced for internal company use in building, chemical and industrial, and metallurgical sectors.

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TABLE 6
U.S. EXPORTS OF LIME, BY TYPE 1/

Type	1999 Quantity (metric tons) 2/	1999 Value 3/	2000 Quantity (metric tons) 2/	2000 Value 3/
Calcined dolomite:				
Brazil	--	--	217	$95,800
Canada	2,050 r/	$483,000 r/	2,490	553,000
Israel	24 r/	31,900 r/	103	25,500
Japan	1,470 r/	358,000 r/	90	27,800
Mexico	320 r/	86,600 r/	197	36,800
Netherlands	25	33,400	149	40,000
Taiwan	809 r/	188,000 r/	772	162,000
Vietnam	--	--	368	108,000
Other 4/	36	17,900	265	88,300
Total	4,730 r/	1,200,000 r/	4,650	1,140,000
Hydraulic lime:				
Canada	10,600	1,280,000	9,680	1,170,000
New Zealand	269	99,800	206	72,900
Other 5/	211 r/	62,600 r/	130	91,400
Total	11,100	1,440,000	10,000	1,330,000
Quicklime:				
Argentina	150	36,400	6,590	1,280,000
Canada	28,300	3,140,000	31,000	3,280,000
Costa Rica	739	124,000	428	63,800
Mexico	7,540	1,240,000	12,400	1,390,000
Russia	--	--	200	19,100
Other 6/	58	20,000 r/	132	202,000
Total	36,800 r/	4,560,000 r/	50,700	6,230,000
Slaked lime (hydrate):				
Bahamas, The	287	47,600	551	89,300
Canada	5,820	840,000	7,040	1,070,000
France	117	39,400	--	--
Philippines	372	81,800	151	17,300
Other 7/	163 r/	66,600 r/	91	81,700
Total	6,760	1,080,000	7,830	1,260,000
Grand total	59,300 r/	8,270,000 r/	73,200	9,960,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ To convert metric tons to short tons, multiply metric tons by 1.10231.

3/ Declared " Free alongside ship" (f.a.s.) valuation.

4/ Includes Egypt, New Zealand, South Africa, and Uruguay.

5/ Includes The Bahamas, Chile, Germany, Haiti, India, the Republic of Korea, Mexico, Spain, the United Kingdom, and Venezuela.

6/ Includes The Bahamas, Barbados, Guatemala, Kuwait, Panama, Slovenia, and the United Arab Emirates.

7/ Includes Antigua, Ireland, Mexico, Taiwan, Trinidad and Tobago, and the United Kingdom.

Source: U.S. Census Bureau.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1999 Quantity (metric tons) 2/	1999 Value 3/	2000 Quantity (metric tons) 2/	2000 Value 3/
Calcined dolomite:				
Canada	29,500 r/	$4,510,000 r/	15,700	$2,750,000
Other 4/	8 r/	8,320 r/	404	310,000
Total	29,500 r/	4,520,000 r/	16,200	3,060,000
Hydraulic lime:				
Canada	26 r/	2,750	1	3,460
Mexico	2,870 r/	189,000	--	--
Total	2,900 r/	192,000	1	3,460
Quicklime:				
Canada	79,100 r/	7,570,000	68,200	6,770,000
Mexico	--	--	701	81,400
Other 5/	89 r/	138,000	246	272,000
Total	79,200 r/	7,700,000	69,200	7,120,000
Slaked lime (hydrate):				
Canada	16,900 r/	1,590,000	12,400	1,210,000
Mexico	11,800 r/	1,490,000	15,400	1,880,000
Other 6/	88 r/	198,000	119	196,000
Total	28,800 r/	3,270,000	27,900	3,290,000
Grand total	140,000 r/	15,700,000 r/	113,000	13,500,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Declared "Cost, insurance, and freight" (c.i.f.) valuation.
4/ Includes China, Spain, and Switzerland.
5/ Includes Australia, Belgium, China, Finland, Japan, Thailand, and the United Kingdom.
6/ Includes Ecuador, Germany, Japan, Montserrat, Taiwan, Thailand, and the United Kingdom.

Source: U.S. Census Bureau.

TABLE 8
LIME PRICES 1/

Type	1999 Dollars per metric ton	1999 Dollars per short ton	2000 Dollars per metric ton	2000 Dollars per short ton
Sold and used:				
Quicklime	57.30	52.00	57.50	52.10
Hydrate	80.20	72.70	85.00	77.10
Dead-burned dolomite	85.40	77.40	88.90	80.60
Average all types	60.40 r/	54.80	60.60	55.00
Sold:				
High-calcium quicklime	56.90	51.70	57.40	52.10
Dolomitic quicklime	55.00	49.90	59.00	53.50
Average quicklime	56.60	51.40	57.60	52.30
High-calcium hydrate	79.10	71.80	80.20	72.70
Dolomitic hydrate	87.90	79.70	103.00 r/	93.30
Average hydrate	80.30	72.80	85.10	77.20
Dead-burned dolomite	82.40	74.80	89.70	81.40
Average all types	59.90	54.40	60.90	55.20

r/ Revised.
1/ Average value per ton, on an f.o.b. plant basis, including cost of containers.

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TABLE 9

QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria e/	1,990 4/	1,900	2,000	2,000	2,000
Belgium e/	1,800	1,750	1,750	1,750	1,750
Brazil e/	5,700	5,700	5,700	5,700	5,700
Bulgaria e/	1,000	1,200	1,100	1,100	1,100
Canada	2,402	2,477	2,514	2,585	2,600
Chile e/	1,050	1,000	1,000	1,000	1,000
China e/	20,000	20,500	21,000	21,500	21,500
Colombia e/	1,300	1,300	1,300	1,300	1,300
Czech Republic	1,176	1,217	1,151	1,200 e/	1,200
France e/	2,714 4/	2,360	2,400	2,400	2,400
Germany e/	7,570 4/	7,600	7,600	7,600	7,600
Iran	2,000 e/	2,500 e/	2,737	2,138	2,200
Italy e/ 5/	3,500	3,500	3,500	3,500	3,500
Japan (quicklime only)	7,744	8,104	7,646	7,594 r/	7,650
Mexico e/	6,600 4/	6,500 r/	6,500 r/	6,500 r/	6,500
Poland	2,461	2,516	2,406	2,500 e/	2,500
Romania	1,712	1,750	1,700	1,700 e/	1,700
Russia 6/	7,822	7,626	7,000	7,000 e/	8,000
South Africa (sales)	1,650	1,585	1,523	1,920 r/	1,345 4/
Spain e/	1,000	1,000	1,000	1,000	1,000
Turkey 7/	1,023	1,170	1,066	1,100 e/	1,100
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States (sold or used by producers) 8/	19,200	19,700	20,100	19,700 r/	19,600 4/
Other e/	8,590 r/	9,050 r/	9,310 r/	9,210 r/	8,760
Total	114,000 r/	116,000 r/	116,000 r/	116,000 r/	116,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 6, 2001.

3/ Lime is produced in many other countries besides those included in the total. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.

4/ Reported figure.

5/ Includes hydraulic lime.

6/ Total industrial and construction production as reported by Russia.

7/ Lime produced for steel production; does not include the widespread artisanal production of lime for whitewash and sanitation purposes.

8/ Includes Puerto Rico.

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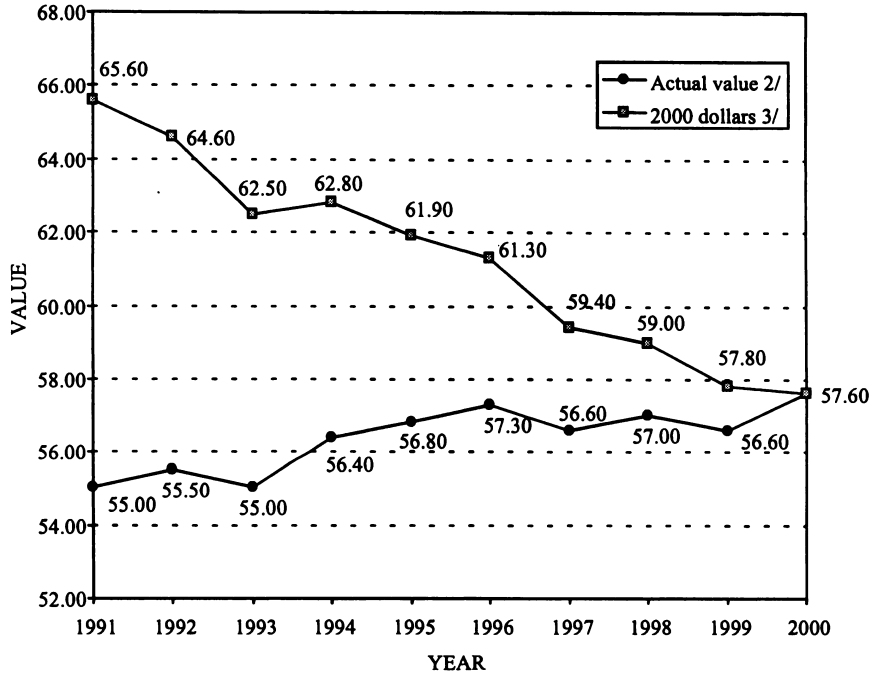
FIGURE 1
TIME-VALUE RELATIONS FOR QUICKLIME SOLD

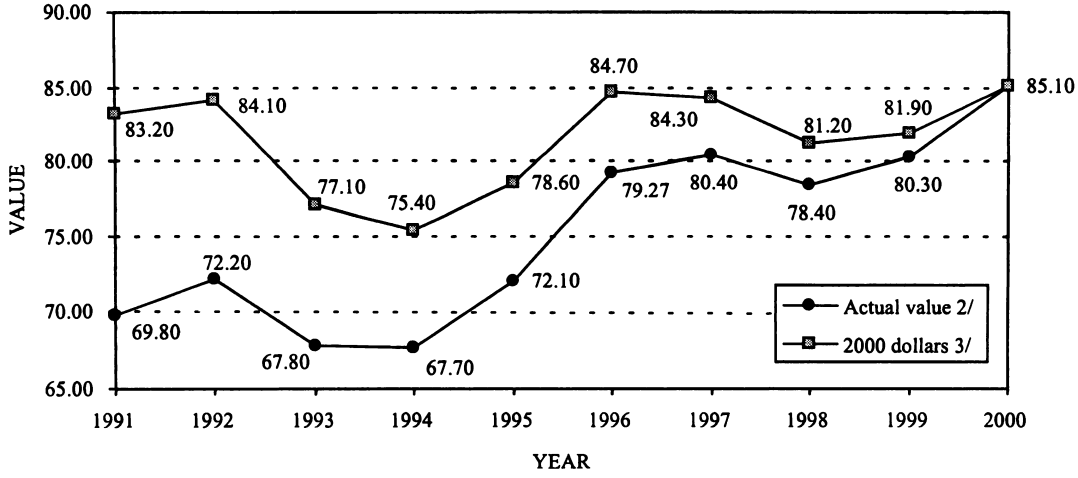
(Dollars per metric ton) 1/



1/ To convert dollars per metric ton to dollars per short ton, divide value by 1.10231.
2/ Based on implicit price deflator for gross domestic product; base year 2000.
3/ Value of quicklime sold as prepared for shipment, f.o.b. plant.

FIGURE 2
TIME-VALUE RELATIONS FOR HYDRATED LIME SOLD

(Dollars per metric ton) 1/



1/ To convert dollars per metric ton to dollars per short ton, divide value by 1.10231.
2/ Based on implicit price deflator for gross domestic product; base year is 2000.
3/ Value of hydrated lime sold as prepared for shipment, f.o.b. plant.

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LITHIUM

By Joyce A. Ober

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant, and the world production tables were prepared by Regina R. Coleman, international data coordinator.

Introduction

Chile was, once again, the world's leading producer of lithium carbonate with production at its two lithium operations on the Salar de Atacama in the Andes Mountains. There was one lithium carbonate plant in Argentina on the Salar del Hombre Muerto, but it operated at a level far below its capacity. In addition, production of lithium chloride continued in Argentina. One lithium carbonate plant continued to operate in Nevada. Chinese and Russian lithium carbonate production continued; Australia, Canada, and Zimbabwe were important sources of lithium ore concentrates.

A large percentage of the material produced in South America was exported to the United States as feed material for the production of downstream lithium compounds and in industrial applications. The United States remained the world's leading producer of value-added lithium compounds and also the leading lithium consumer.

Because lithium is electrochemically reactive and has other unique properties, many commercial lithium products are available. With an estimated market value of $500 million worldwide, producers sell lithium as mineral concentrate, brine, chemical, or metal depending on the end use. Most lithium compounds and minerals are consumed in the production of ceramics, glass, and primary aluminum, although the use of organic lithium compounds as industrial catalysts and the consumption of various lithium compounds in lithium batteries are the most rapidly expanding markets.

Production

The U.S. Geological Survey collects domestic production data for lithium from a voluntary survey of U.S. operations. The single remaining lithium carbonate producer responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data (table 1).

Chemetall Foote Corp., a subsidiary of the German company Chemetall GmbH, produced lithium carbonate from brines near Silver Peak, NV. The company's other lithium operations included a lithium hydroxide plant in Silver Peak; a butyllithium plant in New Johnsonville, TN; and facilities for producing downstream lithium compounds at the site of an idle spodumene (a lithium aluminum silicate ore) deposit in Kings Mountain, NC.

FMC Corp., Lithium Division, produced a full range of downstream compounds, including lithium metal and organic lithium compounds at its facilities in Bessemer City, NC, and Bayport, TX. FMC operated a lithium carbonate plant and spodumene mine in North Carolina until 1998. Since 1999, the company has met its lithium carbonate requirements through a long-term agreement with Chilean producer Sociedad Quimica y Minera de Chile S.A. (SQM) to supply FMC with lithium carbonate produced at SQM's brine operation. FMC determined

Lithium in the 20th Century

In 1900, the lithium industry was practically nonexistent; the United States produced 470 metric tons of lithium minerals, containing less than 10 tons of lithium. Early in the century, several lithium minerals, including amblygonite, lepidolite, and spodumene, were produced in California and South Dakota and were used in specialty glass, enamels, and glazes. Some minerals were shipped overseas for conversion into lithium compounds, especially lithium hydroxide, which was used for batteries and in certain pharmaceutical applications. Domestic lithium chemical production began in 1905. The lithium industry grew significantly during World War II, when lithium compounds were used in military applications. Lithium hydride was used to generate hydrogen to inflate antenna balloons for rescue radios; anhydrous lithium hydroxide was and is still used to absorb carbon dioxide in submarines and later in manned spacecraft. After the war, the lithium industry searched for and promoted industrial uses of lithium compounds to replace markets lost. New markets were developed in the multipurpose grease industry and as welding fluxes. During that time, lithium minerals continued to be used in ceramics and glass, and newly developed pyroceramics (materials that expanded and contracted very little at extreme temperatures) were used in nosecones of spacecraft. These materials were later marketed for cookware that became very popular because of its durability. The United States was the leading producer of lithium materials for most of the 20th century, with spodumene mines in North Carolina being the dominant sources of raw materials and lithium brine operations in California and Nevada becoming other important sources. Chile overtook the United States as the world's leading producer in 1998, the year the final spodumene operation in the United States closed.

In 2000, the United States was still the leading producer of downstream lithium compounds and the leading consumer of all types of lithium materials with an estimated consumption of 2,800 tons of contained lithium. Lithium minerals continued to be important in the ceramics and glass industry. Lithium compounds were used in primary aluminum production, lubricants, lithium battery components, industrial air-conditioning and commercial dehumidification systems, production of sophisticated textiles, sanitizers for swimming pools and public restrooms, and dry bleaches for commercial laundries.

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that the supply agreement with SQM would be more economical than continuing to produce lithium carbonate from its own operation in Argentina that was completed in 1997 (FMC Corp., 2001). FMC produced lithium chloride and minor quantities of lithium carbonate in Argentina in 2000.

LithChem International, a subsidiary of ToxCo, Inc., both of Anaheim, CA, produced lithium carbonate and lithium hydroxide at its facilities in Baltimore, OH. LithChem produces these compounds from lithium compounds that are products of ToxCo's lithium battery recycling operation in Trail, British Columbia, Canada. In 2000, LithChem acquired Ozark-Mahoning Co.'s inorganic fluorine compounds facility in Tulsa, OK, from Atofina Chemicals Inc. and renamed it Ozark Fluorine Specialties Inc. LithChem plans to use some of the hydrofluoric acid produced at Ozark's facility to make lithium hexafluorophosphate, high-purity lithium fluoride, and other electrolytes used in lithium batteries. The lithium electrolyte compounds used in lithium ion batteries currently (2000) are produced commercially by only one company in Japan (Hunter, 2000).

Lithium carbonate is the most important lithium compound produced from brine and ore deposits. In most cases, other lithium compounds require lithium carbonate as a feedstock for further processing. Domestic production of lithium carbonate from brine is limited to Chemetall Foote's operation in Nevada. Nevada brines enriched in lithium chloride, which averaged about 300 parts per million (ppm) when operations began in 1966 (Engineering and Mining Journal, 1970), are pumped from the ground and progress through a series of evaporation ponds. Over the course of 12 to 18 months, concentration of the brine increases to 6,000 ppm lithium through solar evaporation. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped. A similar process is used to recover lithium from the Chilean brines, with slight adjustments to account for their different chemistries. The brine operation in Argentina uses a different, proprietary technology that allows for the lithium recovery as either carbonate or chloride (FMC Corp., 1998).

Until the last domestic mine closed in 1998, spodumene was the major raw material required for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate were produced for sale. Spodumene is the most common lithium ore, but petalite and lepidolite are other types that are mined in different parts of the world. These three are beneficiated to produce lithium ore concentrates that can be used directly in certain applications.

Extracting lithium from spodumene entails an energy-intensive chemical recovery process, which is more costly than that used for brines. Because of the high cost of producing lithium carbonate from spodumene, most lithium carbonate production has shifted to the brine deposits. After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. The concentrate is heated to 1,075° C to 1,100° C, changing the crystal structure of the mineral and making it more reactive to sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250° C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Consumption

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries used most of the lithium minerals and compounds sold in 2000. Estimated domestic consumption has been stable since 1997. Ceramics and glass production and aluminum smelters were the largest consumers of lithium carbonate and lithium concentrates worldwide, representing an estimated 50% of the total lithium market. Other consuming industries were lubricants, 18%; batteries, 9%; catalysts for synthetic rubber and pharmaceuticals, 9%; and other uses, 14% (Schmitt, 2000). Domestic end uses differ from global consumption and are described below.

The largest use of lithium in the United States was in ceramics and glass manufacturing processes. These additions, which can be made as lithium carbonate or ore concentrates, lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic compounds. Lithium ore concentrates were consumed exclusively in the production of ceramics and glass products. The domestic manufacture of thermal shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry. The manufacture of black-and-white television picture tubes consumed significant amounts of lithium concentrates overseas. Low-iron spodumene and petalite were sources of the lithium used to improve the physical properties of container and bottle glass, and sources of alumina, another important component of the glass. Glass manufacturers used lithium in container and bottle glass, enabling them to produce lighter weight, thinner walled products. Until 1997, lithium ore concentrates were the only lithium products that were acceptable for most ceramics and glass applications because of their low cost in comparison to lithium carbonate. Applications sensitive to other elements and impurities that came with ore concentrates and the price of lithium carbonate were not able to take advantage of the benefits of lithium in their production processes. When the lithium carbonate price was cut to about one-half of its previous level, these specialty glass producers were economically able to change their glass formulations to take advantage of the improved properties made possible by lithium additions (Sheets and Rios, 1999).

The second largest use is in primary aluminum production, especially at older smelters. Adding lithium carbonate to aluminum potlines lowers the melting point of the bath, allows a lower operating temperature for the potline, increases the electrical conductivity, and decreases viscosity of the bath. These factors contribute to increased production or reduced power consumption. Perhaps more important are the environmental benefits of lithium addition to aluminum potlines—reducing fluorine emissions by 20% to 30% (Chemetall GmbH, 2001, Lithium applications, accessed April 2, 2001at URL http://www.chemetalllithiumcom/lithium/lithium.nsf/Frame/25083639DDB37807C125693D00491D90).

Domestically, the third largest and the fastest growing end use for lithium compounds was as catalysts in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium initiated the reactions between styrene and butadiene that form abrasion-resistant synthetic rubbers that require no

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vulcanization. Other organic lithium compounds were catalysts for the production of plastics, such as polyethylene. Lithium metal and compounds were catalysts in the production of an analgesic, anticholesterol agents, antihistamines, contraceptives, sleep inducers, some steroids, tranquilizers, vitamin A, and other products. Pharmaceutical-grade lithium carbonate was used in the treatment of manic-depressive psychosis. This was the only treatment approved by the U.S. Food and Drug Administration in which lithium was consumed by the patient.

The multipurpose grease industry was another of the important markets for lithium in 2000. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-based greases were favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be used in military, industrial, automotive, aircraft, and marine applications.

The use of lithium in batteries and the belief that lithium batteries may be the best way to power electric vehicles (EVs) have spurred tremendous interest in lithium and lithium deposits to provide resources for the anticipated increased demand. Almost all major battery manufacturers marketed some type of lithium battery, and research and development continued. New battery configurations continued to be developed and continued interest in EVs drove additional interest in battery research. New, more efficient types of rechargeable (secondary) lithium batteries have been developed and older designs improved to meet the requirements of the EV market and of electronic equipment, such as portable telephones, portable computers, and video cameras. Research continued on lithium-ion batteries. These batteries were of particular interest because they take advantage of the large power capacity available from lithium batteries with fewer safety problems than are encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture. Nissan Motor Corp. U.S.A. introduced its first EV available in the United States at the 1998 Los Angeles Auto Show. The four-passenger minivan was powered by lithium-ion batteries developed jointly by Nissan and Sony Corp. This was the first EV from any automobile company that used lithium-ion batteries (Advanced Battery Technology, 1998).

Nonrechargeable (primary) lithium batteries offer improved performance over alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in watches, microcomputers, cameras, small appliances, electronic games, and toys. The military purchased large and small lithium batteries for a variety of military applications. In 2000, two lithium oxyhalide reserve batteries were qualified for use in different missile programs, the High Altitude Area Defense and the Boeing Ground Based programs. Reserve batteries provide high current for short times from small packages (McHale, 2000).

Aircraft manufacturers in several countries have considered using aluminum-lithium alloys for wing and fuselage skin or structural members in different types of aircraft. Use of these alloys could reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, were attractive to the aircraft and aerospace industries because of their reduced density and superior corrosion resistance compared with conventional aluminum alloys. These alloys, however, have not been as widely used in aircraft manufacture as was hoped at the initial introduction of the alloys. In airplane construction, these alloys faced direct competition from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers. McCook Metals LLC produced an aluminum-lithium alloy that is being used for a fatigue-critical aft bulkhead replacement and other parts on the F-16 fighter plane built by Lockheed Martin Corp. The alloy was produced at the McCook, IL, plant formerly owned by Reynolds Metals Co. (Light Metal Age, 1998).

The National Aeronautics and Space Administration selected a new design by Lockheed Martin Manned Space Systems for the external space shuttle fuel tank; this is the only part that is not reused. The superlightweight tank was made with another aluminum-lithium alloy containing 4% copper, 1% lithium, 0.4% silver, 0.4% magnesium, and the remainder aluminum. This alloy was 30% stronger and 5% less dense than the aluminum alloy previously used. The redesigned fuel tank weighed about 3,400 kilograms less than the original design; the weight savings were used to increase the payload capacity for shuttle missions. Reynolds Metals and McCook Metals were to produce 25 of the redesigned fuel tanks (Light Metal Age, 1998).

Small quantities of other lithium compounds were important to many industries. Lithium chloride and lithium bromide were used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleaches for commercial laundries. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals, such as steel alloys and aluminum.

Prices

Although yearend 2000 published prices for lithium carbonate were the same as those listed in trade publications in 1999, actual prices paid by customers were believed to be significantly lower than those published. The vigorous entrance into the market of SQM in 1998 prompted Chemetall Foote and FMC to reduce their prices comparably, although actual price lists and quotations have been difficult to obtain since the price reductions began. SQM entered the market offering lithium carbonate at about $2.00 per kilogram ($0.90 per pound); effective October 1, 1999, the company raised its price by about 10% to around $2.20 per kilogram ($1.00 per pound) (Industrial Minerals, 1999b). Chemetall and FMC announced price increases of 8% and $0.22 per kilogram ($0.10 per pound), respectively, at the end of 2000, although no specific prices were published (Industrial Minerals, 2000b).

Customs values for lithium carbonate entering the United States from Chile are a good indication of the trends in lithium pricing, although they have never reflected exactly the producers' average prices for lithium carbonate. The average unit value calculated from the U.S. Census Bureau data using Customs value and quantity imported, showed that the unit value of lithium carbonate decreased 46% from 1996 to 1999; the average value increased almost 7% in 2000. The unit value for lithium carbonate from Chile has decreased steadily from $2.70 per kilogram in 1996 to $1.45 in 2000. Imports from Argentina were recorded for the first time in 1998; the unit value for this

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material in 2000 was $3.06 per kilogram. Even the highest values listed here were significantly lower than the published price of $4.47 per kilogram (table 2).

Foreign Trade

Total exports of lithium compounds from the United States decreased significantly in 1998 as compared with the previous years; exports have continued at the lower level. Because of the closures of the spodumene mine and lithium carbonate plant in North Carolina, lithium carbonate production in the United States has decreased substantially. The reduced production made lower exports inevitable. Commitments to overseas customers were supplied from operations in South America. About 68% of all U.S. exports of lithium compounds were to Canada, Germany, India, Japan, and the United Kingdom (table 3).

Imports of lithium compounds increased nearly 10% in 2000. In 2000, 88% of lithium imports was from Chile; and lithium carbonate from Argentina was 7.5% of total imports (table 4). Lithium ore concentrates from Australia, Canada, and Zimbabwe were believed to have been consumed in the United States, but no import statistics were available.

World Review

A small number of countries throughout the world produced lithium ore and brine. Chile and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and ore concentrates also were produced in Argentina, Australia, Canada, Chile, China, Portugal, Russia, and Zimbabwe. Brazil produced smaller quantities, primarily concentrates; Namibia, Rwanda, South Africa, and Zaire are past producers of concentrates. Production figures for lithium ore concentrates and lithium carbonate are shown in table 5. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia, China, and Israel. Companies in France, Germany, Japan, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Argentina.—After only one full year of lithium carbonate production from its lithium brine operation at the Salar del Hombre Muerto in the Argentine Andes, FMC shuttered the facility in July (Brown, 1999) except for limited production for a specialized market (Saller and O'Driscoll, 2000, p. 45). The operation was designed to produce about 12,000 metric tons per year (t/yr) of lithium carbonate and about 5,500 t/yr of lithium chloride (North American Minerals News, 1998), but technical problems and poor market conditions forced FMC to reevaluate its project, choosing to close the facility and purchase most of its lithium carbonate requirements from other sources, SQM in particular. The lithium chloride production line continued to operate (Industrial Minerals, 1999a). A proprietary selective purification process developed by FMC reduced the number of steps required to recover lithium chloride from the brine and reduced the cost of production (FMC Corp., 1998).

Canada.—Tantalum Mining Corp. of Canada Ltd. (Tanco), a subsidiary of Hudson Bay Mining Co., operates a spodumene mine and concentrating plant at Bernic Lake, Manitoba. Avalon Ventures Ltd. was developing the company's Separation Rapids rare metals project in northwestern Ontario not far from the Tanco operation. Avalon was increasing the capacity of its flotation pilot plant to be able to produce large enough volumes to provide potential customers with enough high-grade petalite concentrate for sampling. The company expected to market most of its product to glass and ceramics producers in the Ohio River Valley in the United States (North American Mineral News, 2000b, p. 12).

The Tanco operation and the Avalon project are on opposite ends of a pegmatite body that extends for more than 8 kilometers (5 miles) from Manitoba into Ontario. Amzin Minerals Ltd., the offshore holding company of Bikita Minerals Ltd., the Zimbabwe petalite producer, planned to produce petalite at a site owned by Emerald Fields Resource Corp., a Canadian company, on the same pegmatite body between the Tanco and Avalon operations. This operation was named the Big Mack. A sample was evaluated and approved by Corning Inc. for its acceptability for ceramics and glass uses. Another sample was sent to Zimbabwe to determine if it was appropriate for beneficiation using Bikita technology. If all the tests turned out as expected, construction of a plant with an initial production capacity of 15,000 t/yr of petalite concentrate was to begin by the spring of 2001. Resources at the Big Mack are conservatively estimated at 300,000 metric tons; but only a small portion of Emerald Fields' 18,200 hectares (45,000 acres) have been drilled (Industrial Minerals, 2000a).

Lithium Metal Technologies Inc. (Limtech), a subsidiary of Lithos Corp., both Canadian companies, was evaluating options for expanding its high-purity lithium carbonate plant to produce more than its current 300 t/yr for sale to specialty glass manufacturers. Limtech purifies technical-grade lithium carbonate from about 99.3% purity to a high-purity 99.999% product that can sell for $50 to $70 per kilogram. The company was considering an additional production line with capacity of 1,000 t/yr (North American Mineral News, 2000a).

Raymor Industries Inc. announced the successful development of a process to produce lithium metal directly from spodumene. The process was developed and tested at McGill University's Department of Mining and Metallurgical Engineering under contract with Raymor Industries. Raymor Industries asserted that the new process would entail the lowest production costs and highest purity for lithium metal production. The company was granted exclusive rights to the new technology that was to be patented. For feed stock, Raymor Industries intended to use spodumene mined from its La Motte deposit in Quebec and purchased spodumene (Raymor Industries Inc., 2000). A drilling project at the La Motte deposit estimated reserves at 4.55 million metric tons (Mt) at 1.07% Li_2O from the surface to the depth of 100 meters (m) with an additional 2.5 Mt below 100 m. The first phase of development involved the construction of a concentration plant to process the ore from an open pit mine. Following the completion of the processing plant, Raymor Industries planned to use the new process to produce lithium metal directly from the spodumene ore without going through the steps required by more traditional lithium metal production (North American Minerals News, 1999).

Chile.—With two large brine operations at the Salar de Atacama and their associated lithium carbonate plants, Chile has become the largest lithium carbonate producer in the world. Chemetall Foote's plant first produced lithium carbonate in 1984; it uses its lithium carbonate as feedstock for its

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downstream chemical production in the United States, and supplies its parent company Chemetall's operations in Germany and Taiwan. SQM completed its first full year of production in 1997 and was planning to increase capacity by 8% to 10% from the original 20,000 t/yr (Industrial Minerals, 1999c); the company was considering expanding into downstream compounds by building a butyllithium plant in Texas and facilities to produce battery materials (Schmitt, 2000). Both companies transport concentrated brines from the Salar to lithium carbonate plants in Antofagasta. Because of SQM's agreement to supply FMC's lithium carbonate requirements, the global market was divided evenly between Chemetall Foote and SQM except for smaller quantities from China and Russia (McCoy, 1999).

China.—Lithium carbonate production in China is from domestic and Australian spodumene ore. Production was limited in 1999 because of the availability of lower cost material from Chile (McCoy, 1999). No significant increase in production was expected in the near future. Tibet Lithium New Technology Development Co., formed as a joint venture by China's Geological Research Institute (20%), Tibet Mineral Development Co. (40%), and Yuxin Trading Co. (40%), was developing a lithium project at the Zabuye Salt Lake in Tibet. A 10-year study at the salt lake identified high concentrations of boron, bromine, cesium, lithium, and potassium. Lithium production within 3 years was the goal of the company (Saller and O'Driscoll, 2000, p. 47). Another lithium project at salt lakes in the Qinghai Province was being considered. Pacific Lithium Ltd., a New Zealand company, reached agreement with the Qinghai Province to create Qinghai Lithium Ltd. (QLL), a joint venture, to study and develop the salt lake resource that was discovered in 1965. QLL's lithium resources were estimated at 1 Mt lithium, more than 1 Mt boron, and more than 17 Mt potassium (Pacific Lithium Ltd., 2000, Qinghai Lithium Limited, accessed April 4, 2000, at URL http://www.pacificlithium.com/technology/associations.html).

Germany.—Chemetall GmbH, the parent company of Chemetall Foote, has been a major producer of lithium compounds for many years at its lithium operations in its Langelsheim plant. In 2000, the company expanded its capacity for the production of lithium aluminum hydride by 50%; another facility was built to produce lithium aluminum hydride solutions. Chemetall is the world's leading producer of lithium aluminum hydride, a versatile reducing agent used in the synthesis of active substances in the pharmaceutical industry. It is marketed as a powder, in tablet form, and in solution (Chemetall GmbH, 2000). Chemetall opened a butyllithium plant in Taiwan in 1999 in response to the growth in demand for organic lithium catalysts (Industrial Minerals, 1999a).

Outlook

The health of the lithium industry remains closely tied to the performance of the primary aluminum and the ceramics and glass industries and the economy in general. Changes in consumption of lithium in these industries determine the performance of the entire lithium industry. Because these uses represent such a high percentage of the total lithium market, growth in other areas has a much smaller influence, although battery and catalyst applications are becoming more important. Demand for N-butyllithium continued to increase, and producers considered more capacity increases to meet that demand. Demand for lithium metal for batteries and to some extent for alloys will probably increase, but total consumption of metal will remain low in comparison with the demand for lithium compounds.

Lithium-ion and lithium-polymer batteries appear to possess the greatest potential for growth for the entire lithium industry. First introduced in 1993 with minimal sales, the market for these rechargeable batteries grew to $3 billion in 1998 and is expected to top $6 billion by 2005 (Pacific Lithium Ltd., 2000, Applications markets, accessed April 4, 2000, at URL http://www.pacificlithium.com/profile/markets.html). No estimates of the amount of lithium required for these batteries have been made; but the value of lithium materials sold for battery production was estimated to be $111 million in 1997, with forecasts of an average annual increase of 16% through 2008 (Saller and O'Driscoll, 2000, p. 41). This kind of value growth indicates that material demand could increase at a comparable rate or quite probably more quickly.

Too many unknowns remain, however, to allow for a reliable forecast of the quantity of lithium that will be required for the future EV market. Not only is there the question of whether lithium will be part of the superior EV batteries, but also whether batteries or fuel cells will be the preferred sources of power. In addition, questions as to when and if EVs will make up a significant portion of new car sales in the United States and around the world have been raised. Sales and leases currently lag behind expectations.

Other markets should remain stable with slight growth. Lithium demand could increase dramatically if the technology for nuclear fusion were perfected. This is not expected to take place within the next 25 years and may never occur.

References Cited

Advanced Battery Technology, 1998, Nissan minivan uses Li-ion technology: Advanced Battery Technology, v. 34, no. 2, February, p. 24-25.

Brown, Robert, 1999, FMC upgrades its core industrial, specialty chemicals: Chemical Market Reporter, v. 256, no. 11, September 13, p. 32, 37.

Chemetall GmbH, 2000, Chemetall increases capacity for lithium aluminum hydride: Chemetall GmbH press release, September 1, 1 p.

Engineering and Mining Journal, 1970, Silver Peak gives bright look to Foote Mineral's lithium picture: Engineering and Mining Journal, v. 171, no. 4, April, p. 72.

FMC Corp., 1998, FMC annual report 1998: Chicago, IL, FMC Corp., p. 23, 25.

———2001, FMC annual report 2000: Chicago, IL, FMC Corp., p. 25.

Hunter, David, 2000, LithChem buys Atofina's Ozark Unit: Chemical Week, v. 162, no. 31, August 16, p. 17.

Industrial Minerals, 1999a, FMC suspends Li_2CO_3 production: Industrial Minerals, no. 383, August, p. 9.

———1999b, SQM raises Li_2CO_3 prices: Industrial Minerals, no. 386, November, p. 90.

———1999c, SQM to increase capacity for nitrates, lithium and potash: Industrial Minerals, no. 380, May, p. 9.

———2000a, Amzim & Bikita to develop petalite: Industrial Minerals, no. 392, May, p. 9.

———2000b, Chemetall and FMC raise lithium prices: Industrial Minerals, no. 399, December, p. 30.

Light Metal Age, 1998, Aluminum-lithium alloys: Light Metal Age, v. 56, no. 1-2, February, p. 102-105.

McCoy, Michael, 1999, Chilean inorganics muscle into the market: Chemical & Engineering News, v. 77, no. 31, August 2, p. 11.

McHale, John, 2000, Eagle-Picher designs lightweight batteries for missile applications: Military & Aerospace Electronics, v. 11, no. 7, July, p. 1, 8.

North American Minerals News, 1998, FMC closes Cherryville spodumene; Bessemer City plant now importing Argentinean Li_2CO_3: North American Minerals News, no. 37, March, p. 4.

———1999, Spodumene with 6% Li_2O obtained from Raymor's La Motte lithium deposit: North American Minerals News, no. 55, December, p. 6.

———2000a, Limtech plans to increase lithium carbonate production: North

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American Minerals News, no. 67, December, p. 6.
———2000b, Ontario—Industrial minerals activity increasing: North American Minerals News, no. 67, December, p. 8-12.
Raymor Industries Inc., 2000, Successful completion of semi-industrial tests on the McGill University process for the production of lithium metal and lithium metal purification process to be patented: Raymor Industries Inc. press release, September 5, 1 p.
Saller, Marcus, and O'Driscoll, Mike, 2000, Lithium takes charge: Industrial Minerals, no. 390, March, p. 37-47.
Schmitt, Bill, 2000, Drugs and batteries energize the market: Chemical Week, v. 162, no. 37, October 4, p. 29.
Sheets, Jack, and Rios, Sebastian, 1999, Market change encourages lithium carbonate demand in glass: Glass, v. 76, no. 11, November, p. 356.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

International Strategic Minerals Inventory Summary Report—Lithium. Circular 930-I, 1990.
Lithium. Ch. in Mineral Commodity Summaries, annual.
Lithium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Lithium Resources and Requirements by the Year 2000. Professional Paper 1005, 1976.

Other

Chemical Market Reporter, weekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
European Chemical News (London), monthly.
Industrial Minerals (London), monthly.
Lithium. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Lithium. U.S. Bureau of Mines Information Circular 9102, 1986.
Roskill Information Services Ltd. (London; last reported on lithium in 1994).

TABLE 1
SALIENT LITHIUM STATISTICS 1/

(Metric tons of contained lithium)

	1996	1997	1998	1999	2000
United States:					
Production	W	W	W	W	W
Producers' stock changes	W	W	W	W	W
Exports 2/	2,200	1,880	1,340	1,330	1,310
Imports 2/	884	975	2,590	2,640	2,880
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,700	2,800	2,800	2,800	2,800
World, production 3/	12,700 r/	14,200 r/	14,300 r/	13,800 r/	14,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits.
2/ Compounds.
3/ Mineral concentrate and lithium carbonate.

TABLE 2
DOMESTIC YEAREND PRODUCERS' AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

	1999 e/		2000 e/	
	Dollars per kilogram	Dollars per pound	Dollars per kilogram	Dollars per pound
Lithium bromide, 54% brine: Truckload lots, delivered in drums	12.83	5.83	12.83	5.83
Lithium carbonate, technical: Truckload lots, delivered	4.47	2.03	4.47	2.03
Lithium chloride, anhydrous, purified: Truckload lots, delivered	11.00	5.00	11.00	5.00
Lithium fluoride	16.94	7.70	16.94	7.70
Lithium hydroxide monohydrate: Truckload lots, delivered	5.74	2.61	5.74	2.61
Lithium metal ingot, technical grade: 1,000-pound lots, delivered	85.92	39.05	85.92	39.05
N-butyllithium in n-hexane (15%): Truckload lots, delivered	44.88	20.40	44.88	20.40

e/ Estimated.

Source: Chemical Market Reporter, v. 258, no. 25, December 18, 2000, p. 23, 26; Chemical Market Reporter, v. 257, no. 7, February 14, 2000, p. 39, 42. Prices for week ending December 15, 2000, for 2000 data, and February 11, 2000, for 1999 data.

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TABLE 3
U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY 1/

Compound and country	1999 Gross weight (metric tons)	1999 Value (thousands)	2000 Gross weight (metric tons)	2000 Value (thousands)
Lithium carbonate:				
Australia	8	$92	32	$187
Canada	683	2,450	562	2,020
China	189	681	97	349
Germany	346	1,480	765	2,240
India	14	51	8	29
Japan	901	3,090	903	3,140
Korea, Republic of	33	114	51	184
Mexico	11	50	7	29
Netherlands	70	250	47	170
Taiwan	25	90	28	100
United Kingdom	274	739	179	624
Other	132	471	58	216
Total	2,690	9,550	2,740	9,280
Lithium carbonate U.S.P.: 2/				
Israel	(3/)	18	1	19
Mexico	18	28	3	6
Netherlands	--	--	23	30
Other	5	69	3	299
Total	23	115	30	354
Lithium hydroxide:				
Argentina	132	489	126	446
Australia	205	851	218	6,860
Canada	150	591	144	566
Chile	95	380	27	108
China	19	80	3	100
Germany	545	1,770	627	2,020
India	450	1,410	383	1,080
Japan	1,410	7,870	1,340	6,930
Korea, Republic of	226	948	146	612
Mexico	141	979	99	427
Netherlands	161	571	142	333
New Zealand	54	224	188	780
Philippines	--	--	26	104
Singapore	108	466	60	253
Thailand	74	222	137	377
Taiwan	33	130	2	25
United Kingdom	178	$612	241	$2,220
Other	960	3,660 r/	873	7,840
Total	4,940	21,200	4,780	31,100

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Pharmaceutical-grade lithium carbonate.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS BY COMPOUND AND COUNTRY 1/

Compound and country	1999 Gross weight (metric tons)	1999 Value 2/ (thousands)	2000 Gross weight (metric tons)	2000 Value 2/ (thousands)
Lithium carbonate:				
Argentina	911	$1,710	1,160	$3,550
Canada	(3/)	13	(3/)	3
Chile	12,800	18,700	13,500	19,600
Germany	17	66	(3/)	4
Japan	15	75	2	36
New Zealand	21	88	113	522
Other	23	81	22	63
Total	13,800	20,800	14,800	23,800
Lithium hydroxide:				
Chile	--	--	91	224
China	96	249	367	962
Japan	25	572	19	252
Taiwan	14	50	(3/)	6
Other	119	755	138	659
Total	254	1,630	615	2,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 5
LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
Argentina: e/					
Spodumene and amblygonite	400	697 4/	700	700	700
Carbonate from subsurface brine	--	--	6,000	1,000	1,000
Australia, spodumene	117,094 r/	88,399	63,190 r/	75,824 r/ 4/	76,000
Brazil, concentrates e/	1,600	1,600	1,600	1,600	1,600
Canada, spodumene e/ 5/	22,000	22,500	22,500	22,500	22,500
Chile, carbonate from subsurface brine	14,180	24,246	28,313	28,000	28,500
China, carbonate e/	15,000	15,500	13,000	12,500	13,000
Namibia, concentrates, chiefly petalite	1,972	1,019	500	--	--
Portugal, lepidolite	7,626	6,883	7,000 e/	7,000	7,000
Russia (minerals not specified) e/ 6/ 7/	2,000	2,000	2,000	2,000	2,000
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe 8/	30,929	49,833	28,055	36,691 r/ 4/	37,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Table includes data available through March 29, 2001.
2/ Estimated data are rounded to no more than three significant digits.
3/ In addition to the countries listed, other nations may produce small quantities of lithium minerals. Output is not reported; no valid basis is available for estimating production levels.
4/ Reported figure.
5/ Based on all Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).
6/ These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.
7/ Lithium contained in concentrates and brine.
8/ Amblygonite, eucryptite, lepidolite, petalite, and spodumene.

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MAGNESIUM

By Deboarh A. Kramer

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

U.S. magnesium production in 2000 dropped by 23% from that of 1999. Much of the production decline came in the second half of the year and was attributed to high energy costs in the Pacific Northwest, which affected Northwest Alloys Inc.'s Addy, WA, primary magnesium plant and a cell relining project that was occurring at the Magnesium Corp. of America (Magcorp) Rowley, UT, plant. The shortfall in domestic production was replaced by imports, which, in 2000, reached their highest level, surpassing the 1999 record high. Canada, China, Russia, and Israel, in descending order, were the principal import sources. China supplied mostly magnesium alloys to the United States, Israel and Russia primarily supplied pure magnesium, and Canada supplied both. Aluminum alloying remained the largest use for magnesium in the United States, and although diecasting remained the second largest use for primary magnesium in the United States, 2000 consumption declined significantly, which was attributed to the overall decline in the U.S. economy.

Noranda Magnesium Inc. began commercial operation of its 63,000-metric-ton-per-year (t/yr) plant in the third quarter of 2000 and planned to have the plant fully operational by the first quarter of 2001. Development work continued on other proposed magnesium plants throughout the world, with the most activity in Australia. If all the plants for which completion dates have been announced are constructed, there would be an additional 96,000 t/yr of capacity in Australia onstream by 2003; 103,000 t/yr in Australia by 2004; 60,000 t/yr in Congo (Brazzaville) by 2005; and 80,000 t/yr in Australia by 2006. If other plants proposed in Australia, Canada, Iceland, and the Netherlands are built, there will be an additional 430,000 t/yr of primary magnesium capacity by the end of the decade.

Legislation and Government Programs

The International Trade Administration (ITA) conducted 5-year sunset reviews of the countervailing and antidumping duties for magnesium from Canada, as is required by the Uruguay Round of Agreements Act. The final determinations in these investigations were that revocation of the order would most likely lead to continuation or recurrence of the duties. For the countervailing duty for pure and alloy magnesium, the likely subsidy was 1.84% ad valorem for Norsk Hydro Canada Inc. and 4.48% ad valorem for all others. The ITA determined that the dumping margin for pure magnesium would be 21.00% ad valorem for Norsk Hydro Canada and all others, the amount at which the duty was originally set (U.S. Department of Commerce, 2000d, e). These sunset decisions may have an adverse effect on Noranda Magnesium. The company completed its 63,000-t/yr primary magnesium plant in Quebec in the third quarter of 2000 and planned to sell the magnesium in the United States. Until the company receives a new shipper review from the ITA, if it requests one, the Magnola plant will be required to pay the antidumping and countervailing duties established for "all others" in these sunset reviews. The

Magnesium in the 20th Century

In 1900, all the magnesium metal used in the United States was imported, mostly from Germany. It was not until 1914, when imports were cut off because of the start of World War I, that the first magnesium extraction plant was built in the United States by General Electric Co. At that time, the principal use for magnesium was in munitions, because it created a bright white light when it was burned, and small quantities were used in flash photography. With the end of World War I, requirements for magnesium decreased, but as new civilian uses were developed, such as use as a scavenger and deoxidizer and as an alloying addition to other metals, production grew steadily. The establishment of the national defense program in 1939, which emphasized the importance of magnesium alloys for aircraft and munitions applications, and the outbreak of World War II soon after, led to a huge increase in magnesium production and consumption in the United States. Between 1940 and 1943, the U.S. Government constructed 13 magnesium plants, and U.S. magnesium production reached its peak in 1943 at 167,000 metric tons. Although most of the plants that had been constructed to supply magnesium for defense needs were closed after World War II, ownership in a few was retained by the Government, and these were reactivated in 1950 during the Korean conflict. In the 1960s and 1970s, U.S. production and use of magnesium grew as use of aluminum grew; magnesium's principal application was as an alloying addition to aluminum. Of particular importance was the introduction of the aluminum beverage can in 1958 and its eventual dominance over steel in this application by about 1980.

By 2000, only two magnesium production plants were operating in the United States, with a total capacity of 83,000 metric tons per year, and imports again supplied a significant portion of the U.S. demand. Magnesium recycled from old magnesium and aluminum alloy scrap also supplied a significant portion of U.S. demand. Aluminum alloying was the largest application for primary magnesium, with about 53%, but structural magnesium alloy components, particularly diecastings, have grown to account for about 23% of the total primary magnesium consumed in the United States. Smaller quantities of magnesium were used for desulfurization of iron and steel and as a reducing agent for other nonferrous metals, such as titanium and beryllium.

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company could not participate in the June sunset review process because it was not shipping commercial quantities of magnesium to the United States at that time. Through the NAFTA Secretariat, the government of Quebec appealed the final sunset reviews for the antidumping duty on pure magnesium and the antidumping and countervailing duty orders on magnesium alloy that were completed in July. A decision on the appeals was scheduled to be completed by June 15, 2001, (NAFTA Secretariat, [undated], General information, accessed November 7, 2000, at URL http://www.nafta-sec-alena.org/english/index.htm).

In September, the ITA also completed its administrative reviews of countervailing duties for pure and alloy magnesium from Canada for the 1998 calendar year. For this period, the countervailing duty was established at 1.38% ad valorem for magnesium imported into the United States from Norsk Hydro Canada. The ITA also determined that Norsk Hydro Canada had not sold commercial quantities of magnesium into the United States in a 3-consecutive-year period, so the company did not qualify for revocation of the antidumping duty (U.S. Department of Commerce, 2000c). The ITA also began an investigation of countervailing duties for calendar year 1999.

The International Trade Commission (ITC) revoked the antidumping duty order established in 1995 on magnesium imported from Russia because no interested party responded to the April 2000 request (U.S. International Trade Commission, 2000b). In an expedited 5-year review of the antidumping duty established for pure magnesium from China, the ITC determined that revocation of the duty likely would lead to continuation or recurrence of material injury. Therefore, the antidumping duty of 108.26% ad valorem will remain in effect (U.S. International Trade Commission, 2000a).

At the request of Magcorp, the ITA initiated a countervailing duty investigation of pure magnesium from Israel and antidumping duty investigations of pure magnesium from China, Israel, and Russia. The principal material under concern in these investigations is pure magnesium in granular or powder form, which was specifically excluded from earlier antidumping investigations on magnesium from China and Russia. Antidumping duties for other forms of pure magnesium from China and Russia were established in 1995 and remain in effect. This was the first investigation of magnesium imported from Israel. In its preliminary review, the ITA determined that conditions in the magnesium industry have changed since the initial duties were established, and it is appropriate to include granules and powder in the investigations (U.S. Department of Commerce, 2000a, b).

On April 24, 2001, the ITA announced preliminary dumping determinations on U.S. imports of magnesium from China, Israel, and Russia. The preliminary dumping duties on imports from China were determined to be 8.76% ad valorem for Minmetals Precious & Rare Minerals Import and Export/China National Nonferrous Metals Industry Trading Group Corp. and 305.56% for all other companies in China. For Israel, the preliminary dumping duty was determined to be 12.68% ad valorem for Dead Sea Magnesium Ltd. (DSM), and for Russia, the preliminary dumping duty was determined to be 0% ad valorem. The investigation period for China and Russia was April 1, 2000, though September 30, 2000, and the investigation period for Israel was October 1, 1999, through September 30, 2000. The ITA's final determinations are scheduled to be announced by July 9, 2001, for the duties for Russia and Israel and by September 12, 2001, for the duties for China. If these duty determinations are upheld, importers of magnesium from China and Israel will be required to post a bond equal to the percentage margin of dumping (U.S. Department of Commerce, 2001a, b, c).

The U.S. Environmental Protection Agency (EPA) is planning to collect information on sulfur hexafluoride (SF_6) emissions from companies that produce or cast magnesium. The data collection is part of the EPA's SF_6 Emission Reduction Partnership for the Magnesium Industry, which is one of the agency's voluntary programs that contribute to the overall reduction of greenhouse gas emissions. By joining the partnership, a firm agrees to report an estimate of its SF_6 emissions to the EPA annually. The International Magnesium Association will act as the third party by assembling the data and transmitting it to the EPA to protect individual company proprietary data (U.S. Environmental Protection Agency, 2000).

In November, the EPA held an international conference on emission reduction strategies for SF_6. This conference brought together the electric utility and magnesium industries to discuss and learn about a wide array of issues relating to the use, handling, and management of SF_6. Topics particular to the magnesium industry that were discussed included potential replacements for SF_6, SF_6 recycling, and SF_6 leak detection. Presented papers, poster papers, and PowerPoint presentations from the conference were made available at URL http://www.epa.gov/highgwp1/sf6/agenda.html.

One of the replacements that is being investigated is boron trifluoride (BF_3). Hatch Associates, Mississauga, Ontario, Canada, developed a method of in-line generation of BF_3 that minimizes the need to purchase and store the material as a compressed gas, which can be expensive and hazardous. The company claimed that the patented generation process, called MagShield, protects molten magnesium from oxidation, as well as SF_6, with lower consumption rates, at a lower cost, with fewer workplace emissions, and with no fluoride hazardous waste products generated (Revankar and others, 2000).

Production

In 2000, U.S. primary magnesium production declined by 23% from that of 1999 (table 1). Some of the production decrease can be attributed to rising energy costs, particularly in the Pacific Northwest. Aluminum production in this area has also declined, resulting in reduced need for magnesium for aluminum alloying. This mostly affected Northwest Alloys' plant in Addy, WA. In addition, Magcorp had some of its electrolytic cells offline beginning in the fall, because the company was installing new electrolytic technology that should reduce chlorine emissions. Magcorp expected to complete the installation by the fall of 2002 at a cost of $35 million (U.S. Securities and Exchange Commission, September 11, 2000, Renco Metals Inc.—Form 10-Q, accessed June 12, 2001, via URL http://www.sec.gov/edgar.shtml). Because only two plants remain operating, the U.S. Geological Survey (USGS) can no longer publish U.S. production data to avoid disclosing company proprietary data.

Consumption

Aluminum alloying remained the largest end use for primary and secondary magnesium (tables 3, 4). Reported consumption

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of primary magnesium for aluminum alloying was 53% of the total. Diecasting was the second largest application with 23% of the total reported consumption, and desulfurization of iron and steel ranked third with 12% of the total. In addition to primary magnesium, significant quantities of secondary magnesium are used in iron and steel desulfurization reagents. The total primary magnesium consumed in the United States in 2000 declined by 21% from that of 1999; much of this decline was recorded in the diecasting sector. Although this application continues to be a growth area for magnesium metal consumption, the drop in 2000 was attributed to the overall slowdown in the U.S. economy.

Data for magnesium metal are collected from two voluntary surveys of U.S. operations by the USGS. Of the 81 companies canvassed for magnesium consumption data, 59% responded, representing 40% of the primary magnesium consumption listed in tables 1 and 3. Data for the 33 nonrespondents were estimated based on prior-year consumption levels and other factors. One large nonrespondent accounted for 38% of the 60% of the nonresponse total quantity.

The use of magnesium in automotive applications is continuing to grow. The magnesium content of the 2000 model year North-American-produced vehicles was estimated to be 3.63 kilograms (kg) (8 pounds), a 15% increase from the 1999 model year average of 3.17 kg (7 pounds). Ford Motor Co. planned to continue this growth trend by including magnesium instrument panel support beams in its F-series pickup trucks for the first time. This application was estimated to consume between 5,900 and 8,200 t/yr of magnesium, with each part weighing between 6.8 and 8.2 kg (15 and 18 pounds) each. These would substitute for steel beams in the trucks. Although no specific target year was set for the truck conversion, Ford was beginning to install magnesium alloy instrument panel support beams in the 2001 models of its Explorer sport-utility vehicle (SUV) (Wrigley, 2000d).

Ford announced that it would convert the valve covers on its Triton truck engines to magnesium from plastic, beginning in the 2003 or 2004 model year. The valve covers, which will be made out of AZ91D, will weigh about 3.2 kg (7 pounds). The main reasons for substituting magnesium for plastic are to reduce oil leaks and to improve noise, vibration, and harshness. Ford estimated that about 800,000 engines per year will be used in its pickup trucks, SUVs, and vans, which would consume about 2,500 t/yr of magnesium alloy (Wrigley, 2000b).

Ford also planned to convert the cam covers on some of its truck engines from plastic to magnesium. Beginning with the 2003 model year, Ford will convert the cam covers on its 5.4-liter Triton V-8 engine to AZ91D, and the next model year, the company planned to convert the covers on the 6.8-liter Triton V-10 engine. Estimated magnesium consumption of the cam covers on both engines is about 3,200 t/yr. Spartan Light Metal Products Inc. and Intermet Corp. were expected to be the diecasters for the cam covers. The covers were switched from plastic to magnesium because magnesium has greater creep resistance than the existing plastic covers, and Ford expected that this will lead to fewer service problems (Wrigley, 2000c). With additional parts, such as instrument panel support beams and four-wheel-drive transfer case covers, planned for conversion to magnesium, Ford planned to increase its total magnesium consumption to 78,000 metric tons (t) by the 2004 model year from about 21,000 t in the 2001 model year. Most of the new applications for magnesium will be in the company's SUVs and light-duty trucks (Wrigley, 2000g).

General Motors Corp. (GM) also announced that it would be using about 12 kg (27 pounds) of magnesium alloy diecastings on its new crossover vehicle, the Chevrolet Avalanche, beginning with the 2001 model. The Avalanche is a new type of vehicle that combines the passenger cabin of the Chevrolet Suburban SUV with the cargo box common to pickup trucks. Magnesium components in the new vehicle include four-wheel-drive transfer cases, instrument panel beams, pedal bracket supports, alternator brackets and covers, and the steering wheel armatures (Wrigley, 2000e). In addition, GM was planning to use magnesium alloy support beams in the 2002 models of its new Cadillac roadster model (American Metal Market, 2000).

Lunt Manufacturing Co. entered into a multiyear agreement with GM to manufacture one-piece magnesium alloy instrument panel support beams for the automaker. GM planned to replace the 25-kg (55-pound) steel beams in its 2002 model medium-duty trucks with the magnesium alloy ones, which weigh between 10 and 11 kg (22 and 25 pounds) each. This application was expected to consume 500 to 570 t/yr of alloy AM60. Lunt Manufacturing is only the fourth company in North America that can produce these one-piece beams and will manufacture the components at its Hampshire, IL, facility (Wrigley, 2000j).

For the new 2001 models, North American auto manufacturers were expecting to average between 3.9 and 4.1 kg (8.5 and 9 pounds) of magnesium components per vehicle, a 12.5% increase from the 2000 average. Most of the increase would result from the use of existing part applications in new models. All of the "Big Three" U.S. auto manufacturers (GM, Ford, and DaimlerChrysler Corp.) are using magnesium alloy diecastings in some of their automobiles, trucks, and SUVs. The principal magnesium components will continue to be instrument panel support beams, engine cam covers, four-wheel-drive transfer cases, steering column and pedal bracket supports, and steering wheel armatures (Wrigley, 2000a).

Magnesium also has potential for other automotive applications. GM is interested in a metal hydride fuel cell system using powdered magnesium alloy for its new Precept vehicle, a high-mileage vehicle that uses a combination of electric motors and a small diesel engine. The Precept is the result of the Partnership for a New Generation of Vehicles, a consortium backed in 2000 by $250 million in Federal funding and $980 million from GM, Ford, and DaimlerChrysler. The magnesium-alloy-metal hydride fuel system was developed by Energy Conversion Devices Inc.'s subsidiary Ovionics Battery Co. Because the hydrogen is stored as a solid rather than as a gas or liquid, the need for large storage tanks is eliminated (Wrigley, 2000i; Energy Conversion Devices Inc., [undated], Ovonic hydrogen generation, accessed at URL http://www.ovonic.com/hydrogen/technology.html).

Magnesium also was being used for large components in concept and limited-production vehicles. BMW AG of Germany equipped its Z22 concept car with a cast magnesium cylinder block. Saleen Inc., a specialty vehicle manufacturer based in California, created a high-performance, light-metals-intensive production car called the S7. Magnesium is used in engine components in the vehicle, along with such materials as beryllium and titanium. Only 300 to 400 vehicles were expected to be produced over the 4-year production run (Light Metal Age, 2000). DaimlerChrysler was also using significant quantities of magnesium in its ESX3 concept hybrid-electric

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family vehicle. Magnesium components were substituted for steel as a radiator enclosure, as an instrument panel support beam, and as A pillars (Wrigley, 2000f).

The Swiss ferroalloys producer Xstrata AG announced that it reached an agreement to acquire the Magnesium Services International fluxless magnesium recycling technology, which produces secondary magnesium diecasting alloys using 100% scrap as the feed material. As a result, Xstrata has begun a feasibility study on the construction of a 25,000-t/yr magnesium recycling plant in the Midwestern United States (Platt's Metals Week, 2000g).

TAC Manufacturing Inc., a subsidiary of the Japanese firm Tokai Rika Co., announced that it would install magnesium casting equipment at its existing facility in Jackson, MI, to produce magnesium steering wheel locks. The cost of the new equipment was estimated to be about $10 million. The company already supplied steel and zinc automotive parts to Toyota Motor Corp.'s auto manufacturing plants in the United States. The company planned to sell the magnesium parts to Toyota, as well as other U.S. manufacturing firms (Furukawa, 2000b).

Stocks

Producers' yearend 2000 stocks of primary magnesium declined slightly from those at yearend 1999; these data cannot be reported to avoid disclosing company proprietary data. Consumer stocks of primary and alloy magnesium increased to 7,550 t at yearend 2000 from 6,980 t at yearend 1999. Yearend 2000 consumer stocks of secondary magnesium increased to 2,360 t from the 1999 level of 783 t (revised).

Prices

Quoted magnesium prices declined during 2000, reflecting the oversupply of magnesium in the world market. The Metal Bulletin free market price range for pure magnesium started the year at $2,450 to $2,550 per metric ton and dropped to $1,900 to $2,000 per metric ton by yearend. The China free market price range declined from $1,520 to $1,570 per metric ton to $1,300 to $1,310 per metric ton by yearend.

Platt's Metals Week's European free market price decreased from a range of $2,250 to $2,350 per metric ton at the beginning of the year to $1,800 to $2,000 per metric ton by yearend. The Platt's Metals Week U.S. spot western price dropped from a range of $1.40 to $1.45 per pound at the beginning of 2000 to $1.23 to $1.30 per pound at yearend. The Platt's Metals Week U.S. spot dealer import price decreased from a range of $1.25 to $1.32 per pound at the beginning of the year to $1.05 to $1.15 per pound by yearend.

Foreign Trade

Total magnesium exports for 2000 were about 18% lower than those in 1999 (table 5). Canada (63%), the Netherlands (12%), and Mexico (8%) were the main destinations. Imports for consumption in 2000 were slightly higher than those in 1999 (table 6), and continued to reach new high levels. Canada (40%), China (24%), Russia (15%), and Israel (9%) were the principal import sources in 2000. Russia, Israel, and Canada, in descending order, were the principal sources of imported metal. Canada and China were the principal sources of imported alloys.

World Review

According to figures published by the International Magnesium Association (IMA), world magnesium shipments in 2000 were 367,000 t, which was slightly lower than those of 1999. The data, however, are not exactly comparable; in 1999, the IMA includes shipments of recycled diecasting scrap by the primary producers, and these data were not included in 2000. Aluminum alloying, with 45% of total shipments, was the largest end-use category for magnesium, followed by diecasting with 30% and desulfurization with 14%. Yearend 2000 world inventories increased slightly to 46,500 t representing an estimated 45 days of supply, based on the previous 12 months of shipments (International Magnesium Association, 2001).

After an investigation that began in June 1999, the European Commission recommended an antidumping duty of 63.4% on imports of magnesium from China. This was a significant increase from the 31.7% that has been in effect since 1998 (Platt's Metals Week, 2000e). The Chinese producers were expected to appeal this duty, although several producers reportedly sold magnesium at prices lower than the Chinese Magnesium Association's minimum reference price of $1,500 per metric ton (Platt's Metals Week, 2000c).

Australia.—In March, Australian Magnesium Corp. Ltd. (AMC) completed its feasibility study on construction of a new magnesium plant in Stanwell, Queensland. The study estimated that capital costs for a 96,000-t/yr plant would be $759 million and that operating costs would be between 58.1 and 63.8 cents per pound. (The range in operating cost is based solely on varying exchange rates between Australian and U.S. dollars.) Under a restructuring proposal, Queensland Metals Corp. Ltd. (QMC) will acquire Normandy Mining Ltd.'s 50% interest in AMC in exchange for 225 million shares of QMC. Once a commitment to commercialization of the AMC magnesium plant is made, these shares will be distributed to Normandy's shareholders (Queensland Metals Corp. Ltd., March 28, 2000, AMC feasibility study completed, accessed April 25, 2000, via URL http://www.normandy.com.au; Queensland Metals Corp. Ltd., April 5, 2000, AMC ownership optimised, accessed April 25, 2000, via URL http://www.normandy.com.au).

AMC entered into an alliance with VAW Aluminium AG to develop a magnesium engine block in hopes of providing additional funding for AMC's proposed magnesium plant. If the magnesium engine block is commercialized, AMC would be VAW's exclusive supplier of magnesium alloy for the first 5 years of production. AMC already has a 45,000-t/yr offtake agreement with Ford that provides much of the financing for its pilot plant (Metal Bulletin, 2000a). The company also received all governmental and environmental approvals for the construction of a commercial plant and expected that the plant would come onstream in 2003 (Metal Bulletin, 2000b).

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Queensland government each planned to contribute $A50 million to assist Australia's fledgling magnesium industry. CSIRO's contribution would assist in the commercialization of AMC's process technology, and the Queensland government's contribution would be used to develop a light-metals industry precinct in Stanwell. The Stanwell Energy Park was expected to be developed over the next decade to include magnesium production, diecasting, chemical, and associated service industries (Australian Magnesium Corp. Ltd., November 14, 2000, $100 million

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Federal & Queensland government commitment, accessed December 9, 2000, via URL http://www.austmg.com). AMC also planned to outsource its research and development activities to CSIRO as part of a 4-year agreement. The new agreement covered two major research areas—improving primary magnesium process technologies and developing new value-added applications and improved methods for producing magnesium components, such as alloys, casting, melt, and recycling systems (Australian Magnesium Corp. Ltd., December 7, 2000, AMC to contract CSIRO in research & development alliance, accessed December 9, 2000, via URL http://www.austmg.com).

Pima Mining NL reported that it raised $3.5 million for further development of a proposed magnesium plant by placing 18.2 million shares to institutional investors. The company, through its 80%-owned SAMAG Ltd. subsidiary, planned to construct a 52,500-t/yr primary magnesium plant in Port Augusta, South Australia, using technology acquired from Dow Chemical Co. SAMAG was in the final stages of selecting design engineers and construction contractors. An earlier feasibility study for the project indicated that the capital cost for the plant would be $375 million, and the operating cost would be less than 60 cents per pound of magnesium (Metal Bulletin, 2000j).

In May, SAMAG began trial mining of its magnesite deposit in South Australia. The company planned to mine about 2,000 t of ore for trial leaching tests. The company selected Port Pirie as the site for its proposed 52,500-t/yr magnesium plant because of its existing infrastructure (the Pasminco zinc smelter is located at the same site), rail link between Port Pirie, and the location of the magnesite raw material near Leigh Creek. Initial investment in the plant was expected to begin in 2001, with commercial production scheduled for 2004 (Metal Bulletin, 2000k).

SAMAG purchased the Myrtle Springs and Huandot magnesite deposits from Unimin Australia Ltd., which increased SAMAG's total magnesite resources in the Leigh Creek area in the Northern Territory to 579 million metric tons. This magnesite would provide additional resources for its planned magnesium plant (Pima Mining NL, November 28, 2000, SAMAG purchases additional magnesite resources, accessed January 8, 2001, at URL http://www.pima.com.au/temp.asp?t=asx28nov00). The company also entered into a long-term sales agreement with Germany's ThyssenKrupp Metallurgie GmbH for all of SAMAG's proposed output of magnesium metal and alloys. The agreement allowed SAMAG to receive a guaranteed base price that is sufficient to service the project's debt finance requirements (Pima Mining NL, November 16, 2000, SAMAG signs metal sale agreement with German industrial giant Thyssen Krupp, accessed November 28, 2000, at URL http://www.pima.com.au/temp.asp?t=asx16nov00).

The Council for Minerals Technology (Mintek) of South Africa planned to test a new magnesium production process at a pilot plant that was scheduled to start operation by yearend. The new process is a derivative of the Magnetherm process in which dolomite is reduced with ferrosilicon and alumina to produce magnesium vapor. In Mintek's process, the process is carried out at atmospheric pressure at about 1,700° C compared with operating at a vacuum at 1,550° C to 1,600° C for the Magnetherm process. By operating at atmospheric pressure, rather than in a vacuum, the reduction process can be carried continuously, rather than as a batch process, which may have economic advantages. Mintek planned to evaluate the process for 3 to 6 months before deciding if it is suitable for commercial-scale development and estimated that a 50,000-t/yr plant would require a capital investment of $200 to $250 million (Metal Bulletin, 2000l). Immediately after this announcement, Mintek signed a technology license agreement with Australia's Mt. Grace Resources NL, whereby Mt. Grace Resources would fund the demonstration project and, if test work was successful, use the process to recover magnesium from its Batchelor magnesite deposit in the Northern Territory. Mt. Grace Resources planned to test the new process along with the Heggie aluminothermic process to determine which would be the more economically attractive (Mt. Grace Resources NL, October 6, 2000, Mintek magnesium production technology licence and project option agreement, accessed October 17, 2000, at URL http://www.mtgrace.com/releases/oct_6_2000.html).

In October, Mt. Grace Resources began bulk magnesite mining operations at its Batchelor magnesium project. The company planned to mine and stockpile 2,000 t of magnesite to provide sample material for test work. An ore parcel was scheduled to be sent to Mintek in Johannesburg in January 2001 for testing (Mt. Grace Resources NL, October 30, 2000, Mt[.] Grace Resources mines ore at Batchelor, accessed November 8, 2000, at URL http://www.mtgrace.com/releases/oct_30_2000.html). Mt. Grace Resources planned to complete a 50,000-t/yr magnesium plant by 2004.

Golden Triangle Resources NL produced its first magnesium metal in November. The company is using serpentinite tailings from the former Woodsreef Mine in New South Wales as feedstock. Golden Triangle also announced the development of a new electrolysis system, for which it has applied for a patent. According to the company, the new system will combine magnesium chloride dehydration, electrolyte purification, and electrolysis in one apparatus. Additionally, the apparatus will include the preparation of magnesium alloys. The new electrolytic system, which was developed by the Joint Israeli-Russian Laboratory for Energy Research at Ben Gurion University, will also have the added advantage of significant energy savings in the magnesium production process (Golden Triangle Resources NL, November 28, 2000, Re: Revolutionary new magnesium electrolyzer, accessed January 8, 2001, at URL http://www.goldentriangle.com.au/28Nov00.htm). Golden Triangle Resources planned to construct an 80,000-t/yr plant by 2006.

Canada.—In spite of a fire in one of the four electrolytic cells on August 12, Noranda Magnesium planned to open its Magnola magnesium plant in Quebec by the first quarter of 2001. Noranda produced its first magnesium metal late in October, and 2 out of 24 electrolytic cells had been commissioned. When the 63,000-t/yr plant opens, it will be the first in the world to use asbestos tailings as a raw material for magnesium production (Platt's Metals Week, 2000h; Canada Newswire, October 25, 2000, Noranda produces first magnesium metal, accessed October 31, 2000, at URL http://newswire.ca/releases/October2000/25/c6547.html).

Cassiar Magnesium Inc. (formerly Cassiar Mines & Metals Inc.) expected to complete a feasibility study on its planned magnesium project by the end of 2000. The company hopes to construct a 90,000-t/yr primary magnesium facility in British Columbia by 2003. Cassiar Magnesium planned to present the

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study results to Aluminium of Korea Ltd. (Koralu), with which it has a memorandum of understanding for an initial investment. If, after assessing the study results, Koralu opts to fund the $600 million project, it would have the option to acquire a 65% stake in the plant (Metal Bulletin, 2000d).

Meridian Technologies Inc. was planning to construct its second magnesium diecasting facility in Strathroy, Ontario, which would bring the company's total number of facilities to four. In addition to the two plants in Ontario, Meridian operates plants in Eaton Rapids, MI, and Verres, Italy. Capacity at the new facility is estimated to be 5,000 t/yr of AZ91D and the AM series of alloys (Wrigley, 2000h).

China.—Norsk Hydro A/S announced that it would build a magnesium alloy facility in China. Production capacity of the plant will be 5,000 t/yr, and it will use magnesium produced in China as the feed material. Norsk Hydro planned to have the plant, which will be located in Xian, operational by early 2001. Alloy ingot produced at the plant was expected to be marketed to Norsk Hydro's customers throughout the world (Norsk Hydro A/S, April 20, 2000, Hydro Magnesium goes to China, accessed April 21, 2000, via URL http://www.hydro.com). In addition, Norsk Hydro Magnesiumgesellschaft mbH planned to build a magnesium anode facility in China at the same site. Initial production capacity was expected to be 400 t/yr, perhaps expanding to 800 t/yr. The principal market for the anodes is hot-water heaters in China and Southeast Asia. No timetable was given for plant startup (Norsk Hydro A/S, April 25, 2000, Magnesium in China—Step two, accessed July 7, 2000, via URL http://www.hydro.com).

Because of pollution problems and weak prices, many small magnesium plants in Henan and Shanxi Provinces closed by September. Some of the larger plants were expected to close for a short period to make process upgrades to reduce pollution. The Chinese magnesium export market was reported to be slow, particularly to countries in Europe because of the potential of higher antidumping duties (Metal Bulletin, 2000e). In spite of the world oversupply and plant closures, Chinese magnesium producers continued to announce production expansions at some plants. Yinguang Magnesium Industry Group's new 5,000-t/yr expansion was expected to be completed in December; this would bring the plant's total capacity to 20,000 t/yr of magnesium and magnesium alloy. Shanxi Top Magnesium Co. planned to increase its capacity by yearend 2000 to about 10,000 t/yr from 7,200 t/yr (Platt's Metals Week, 2000j).

The Ningxia Magnesium Metal Works was declared bankrupt in September. Production at the 1,400-t/yr plant had stopped in March 1999, and the state was planning to auction off the plant once the final auditing was complete (Platt's Metals Week, 2000a). Tongxiang Magnesium Industry Co. halved its magnesium output for the second half of 2000, according to company officials. The cutback, to 1,000 metric tons per month (t/mo) from 2,000 t/mo, was in response to declining prices. Tongxiang exported most of its product to Japan and to the Republic of Korea (Platt's Metals Week, 2000i).

An official from the Chinese Magnesium Association stated that China planned to construct a 50,000-t/yr magnesium plant in Qinghai by 2005 using the salt lake resources in the area as feedstock. New plant construction would be funded by the Government and by Minhe Magnesium Co., which operated a 7,000-t/yr magnesium plant in the province (Platt's Metals Week, 2000b). This plant, if constructed, would be China's largest individual plant.

Czech Republic.—Magnesium Elektron, a unit of the Luxfer Group, selected a site northwest of Prague to build a 10,000-t/yr secondary magnesium plant. An unoccupied manufacturing plant was located at the site, and Magnesium Elektron planned to refurbish the building for use as a magnesium recycling plant. The new plant, which will use magnesium alloy scrap from Germany as its feedstock to produce casting alloys, is expected to begin commercial operation in mid-2001 at an initial operating capacity of 7,500 t/yr. The finished product will be exported to German customers, and the plant will gradually ramp up its capacity to 10,000 t/yr by 2002, with an option to increase to 20,000 t/yr if the market warrants it (Metal Bulletin, 2000h).

Israel.—The Board of Directors of Israel Chemicals Ltd. approved the transfer of a majority stake (65%) in DSM from Dead Sea Works Ltd. to Israel Chemicals, the parent company, at a cost of $66.3 million; Volkwagen AG of Germany owns the remaining 35%. Israel Chemicals also would absorb DSM's $111 million in bank debts (Platt's Metals Week, 2000f).

In March, DSM was qualified by DaimlerChrysler to supply magnesium alloys AZ91D, AM50A, and AM60B for use by all of the company's diecasters and was in the initial stages of negotiating with GM to supply it with magnesium alloys. DSM also was in the process of increasing production at the facility in 2000 to 30,000 t of magnesium metal and 24,000 t of magnesium alloys, and the company was proceeding with the construction of its direct-chill caster for producing magnesium T-bar ingot (Platt's Metals Week, 2000d).

Japan.—Japan's Nippon Kinzoku Co. Ltd. completed a 2,400-t/yr magnesium recycling plant in Kitakami, Iwate Prefecture, that was expected to begin commercial production in January 2001. The completion of this plant raised the company's total recycling capacity to 8,000 t/yr. Nippon Kinzoku operated three other magnesium recycling plants in Japan (Furukawa, 2000a).

Netherlands.—A preliminary feasibility study on the Antheus Magnesium Development Programme Delfzijl proposed magnesium plant in the Netherlands was completed. The study was for a combined magnesium smelter, diecasting plant, and recycling plant, all at the same location. Projected capacity of the magnesium smelter would be 15,000 t/yr, with potential expansion to 30,000 t/yr. With the projected sale of excess chlorine generated at the plant, operating costs for the plant were estimated to be about 60 cents per pound. A feasibility study was expected to be completed by early 2001, and a decision on plant construction was expected by the end of 2001 (Brooks, 2000).

Russia.—Russia's Uralasbest, the country's largest asbestos producer, announced that it planned to construct a 50,000-t/yr primary magnesium plant using tailings from the company's asbestos production as its magnesium source. Uralasbest reportedly has constructed a pilot plant based on technology developed at the Solikamsk magnesium plant to recover the magnesium from the tailings, which contain about 24% magnesium. The cost of building a commercial-scale plant was estimated to be about $300 million, and the regional government was planning to issue recommendations on the proposal (Interfax Mining & Metals Report, 2000b).

The European Bank for Reconstruction and Development planned to grant $95 million to the Solikamsk magnesium plant by the end of 2000. The grant was targeted toward increasing

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magnesium production by 100% in 2001. In 1999, Solikamsk produced 9,000 t of primary magnesium and 9,200 t of magnesium alloys (Interfax Mining & Metals Report, 2000a).

Serbia and Montenegro.—The 5,000-t/yr primary magnesium plant in Serbia reportedly restarted production at the end of 1999. The plant had been shut down because of the NATO bombing in the area. Although small quantities of magnesium were produced, it was uncertain whether commercial quantities of magnesium would be produced again (Metal Bulletin, 2000i).

Taiwan.—Norsk Hydro and Taiwan's CS Aluminium Corp. were discussing the construction of a magnesium recycling plant in Taiwan. Although the project was in the planning stage and no details were disclosed, the project was expected to collect magnesium diecasting scrap from Taiwanese firms and recover it in the form of high-purity alloys (Metal Bulletin, 2000f).

Taiwan's Sheng Yu Steel Co. announced that it would complete construction of a magnesium alloy casting plant in Pingnan by early 2001. The plant will produce magnesium alloy covers for computer laptops, digital cameras, and electronic appliances (Metal Bulletin, 2000c).

Ukraine.—MMD-Mineral hoped to restart the Kalush magnesium plant, which had been idle since 1998. The 10,000-t/yr plant had operated using byproduct magnesium chloride salt from a nearby fertilizer operation as its raw material before it closed because of lack of raw material and high operating costs. MMD-Mineral planned to use bischofite ($MgCl_2 \cdot 6H_2O$), which it extracted at a nearby operation, as an alternative raw material source and use technology similar to that used by DSM in Israel. Much of the magnesium plant was owned by the Ukrainian Government, and tender for the magnesium plant, which needed about a $50 million investment for refurbishment, was expected sometime in 2001 (Metal Bulletin, 2000g).

Current Research and Technology

Noranda developed a new family of magnesium alloys with elevated temperature properties equal to or better than those of the magnesium alloy AE42, which can be sold at a lower cost. Unlike AE42, which normally is used in aerospace applications and contains expensive rare earth elements, the new alloys contain magnesium, 5% aluminum, an unspecified quantity of strontium, which is added to improve heat resistance, and a small quantity of manganese, which is added for corrosion resistance. According to Noranda, these alloys demonstrated excellent creep and mechanical properties between 150° C and 175° C and had salt-spray resistance equivalent to that of AZ91D and of the AM series of magnesium alloys. Because of the enhanced properties, the new alloys could be suitable for automotive applications such as automatic transmission casings, engine fan components, oil pumps, and oil pans (Advanced Materials & Processes, 2000b; Pierre Labelle, Mihriban Pekguleryuz, Don Argo, Mike Dierks, Todd Sparks, and Ted Waltematte, [2001], Heat resistant magnesium alloys for power train applications, accessed June 18, 2001, at URL http://www.my.noranda.com/NR/rdonlyres/00001d27cvfandndmjmzqeci/HeatResistantMgAlloys1.pdf).

At Honda Motor Corp., researchers also developed a creep-resistant magnesium alloy for use in oil pans in the engines of Honda's hybrid cars. The new alloy ACM522 also uses a magnesium/5%-aluminum alloy as the basic constituent, but contains 2% calcium, 2% cerium mischmetal, and 0.3% manganese. This new alloy has creep resistance characteristics that are superior to AE42 and has resistance to both heat and corrosion that are similar to those of aluminum alloy A384. Magnesium oil pans made from this alloy are 35% lighter than the aluminum ones that they replace (Kioke and others, 2000).

Researchers at Pacific Northwest National Laboratories and Thixomat Inc. developed a casting process for a series of magnesium-zinc-aluminum-calcium alloys that demonstrates high creep resistance at temperatures up to 175° C. Although this family of alloys has demonstrated improved high-temperature properties, it has exhibited castability problems when it is die-cast. To alleviate this problem, the alloys were cast by the Thixomolding process, then evaluated for creep resistance, moldability, and tensile and compressive strengths. Thixomolding is a patented high-speed injection molding of semisolid thixotropic alloys, which yields high-quality, net-shape magnesium components (Advanced Materials & Processes, 2000c).

Scientists at Wright-Patterson Air Force Base were developing new aluminum-magnesium-scandium alloys for aerospace applications to replace titanium in certain components. By developing high-temperature aluminum alloys, the cost and lead time for the parts could be reduced. Magnesium is present in the alloys because of its strengthening capability. The alloys were in the initial stages of development (Advanced Materials & Processes, 2000a).

Researchers at Bar-Ilan University in Israel announced the construction of the first rechargeable battery based on magnesium. According to the researchers, the new battery can be charged more than 2,000 times and produces up to 1.3 volts of power, which is similar to existing rechargeable batteries. Although magnesium batteries already exist, they are used mostly in military applications and are not rechargeable. By using electrolyte solutions based on magnesium organohaloaluminate salts and $Mg_xMo_3S_4$ (where x is between zero and one) cathodes, the researchers can produce a battery that is about the size of a computer monitor. The new batteries were expected to be commercially available within a year and to be used as uninterrupted power supplies for computer networks affected by power outages (Aurbach and others, 2000).

The French producer of magnesium casting systems Brochot SA developed a new casting wheel designed to minimize surface oxidation when casting magnesium and magnesium alloys. The company applied for a patent of its design, which was adapted from the design of a casting wheel for aluminum systems. By redesigning the points at which the molten metal is delivered to the casting wheel, metal turbulence is reduced, thus minimizing the surface area available for oxidation. In addition, Brochot has replaced the SF_6 protective cover gas with a patented mixture of carbon dioxide, argon, and xenon (Brown, 2000).

Ford was sponsoring research, through the Department of Commerce's Advanced Technology Program, to develop an innovative magnesium diecasting process to be used to cast large components from magnesium alloys. The objective of the 4-year project was to develop a multiport injection "hot runner" system for introducing magnesium into die cavities at a controlled temperature and flow rate. The new process is expected to increase yields and reduce scrap by 10%, thus lowering diecasting production costs (National Institute of Standards, October 2000, Cost-reduced magnesium die castings

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using heated runners (CORMAG), accessed January 26, 2001, at URL http://www.nist.gov/public_affairs/atp2000/00004334.htm).

In May, the IMA selected the Foundation of Scientific and Industrial Research at the Norwegian University of Science and Technology to conduct research on alternative materials for SF_6 in magnesium production and casting operations. The proposed activities of the research team include evaluating the performance characteristics of recently proposed alternatives and seeking out and testing new alternatives, evaluating the addition of minor elements on protective film formation, and optimizing delivery of the most promising alternatives. Research progress will be openly reported to benefit the entire magnesium industry and will be reported annually at the IMA meeting (U.S. Environmental Protection Agency, November 20, 2000, SF_6 and the environment—Understanding, measuring, and managing, accessed June 15, 2001, via URL http://www.epa.gov/highgwp1/sf6/agenda.html).

Outlook

Although magnesium alloy diecasting applications continue to be a growth area for the use of magnesium in the United States, magnesium most likely will remain in an oversupply situation. Growth in diecastings will be offset by some declines in other applications. Aluminum alloying applications in the United States are likely to decline in the near term. High energy prices in the Pacific Northwest, where the most significant portion of the U.S. aluminum production is located, and increased demand for power in California have caused temporary closure of a significant portion of the aluminum production capacity. By yearend 2000, companies announced the temporary closure of 1.03 million metric tons per year (Mt/yr) of capacity, almost two-thirds of the smelters' engineered capacity of 1.64 Mt/yr (CRU International Ltd., 2001). Although some of this capacity may return to operation as energy prices decline, U.S. aluminum production will probably decline in 2001. Through March 2001, U.S. primary aluminum production was 27% less than that in the same period of 2000; comparing the same periods, secondary aluminum recovery from new and old scrap also declined by 12% (Plunkert, 2001). As a result of this projected decline in U.S. aluminum production, magnesium use in this, its largest application, is also projected to decline.

Potential new capacity from proposed plants in Australia that is scheduled to come onstream within the next 5 years could also add to the oversupply situation that has developed. Because of this proposed capacity, capacity at smaller, older plants is being reevaluated. Alcoa Inc. announced that it would close its Northwest Alloys plant by October 31, 2001, citing high production costs and unfavorable market conditions (Alcoa Inc., June 22, 2001, Alcoa shuts down Northwest Alloys magnesium smelter, accessed July 2, 2001, at URL http://www.alcoa.com/site/news/news_release/73157-2001_06_22.asp). Pechiney announced that it may close its 17,000-t/yr primary magnesium plant in Marignac, France. Although no final decision has been made, the company was claiming that competition from low-priced imports of Chinese magnesium led to heavy financial losses at its plant for the past 2 years (Metal Bulletin, 2001). In the short term, closure of these plants, particularly the U.S. plant, is likely to lead to increases in imports from such areas as China and Russia. In the longer term, the elimination of some suppliers may provide additional customers for the proposed plants; this increases the likelihood of more of these new plants actually being constructed.

References Cited

Advanced Materials & Processes, 2000a, Al-Mg-Sc alloys made for high strength at high heat: Advanced Materials & Processes, v. 158, no. 4, October, p. 13-14.

———2000b, Magnesium alloy developed for improved creep resistance: Advanced Materials & Processes, v. 157, no. 6, June, p. 20-21.

———2000c, Magnesium alloys have high creep resistance at high heat: Advanced Materials & Processes, v. 157, no. 6, June, p. 19.

American Metal Market, 2000, New Cadillac to use magnesium beam: American Metal Market, v. 108, no. 209, October 30, p. 20.

Aurbach, D., Lu, Z., Schechter, A., Gofer, Y., Gizbar, H., Turgeman, R., Cohen, Y., Moshkovich, M., and Levi, E., 2000, Prototype systems for rechargeable magnesium batteries: Nature, v. 407, no. 6805, October 12, p. 724-726.

Brooks, David, 2000, Feasibility study to begin on Delfzijl project: Metal Bulletin, no. 8478, May 25, p. 7.

Brown, R.E., 2000, Improved magnesium casting method: Light Metal Age, v. 58, no. 7-8, August, p. 64.

CRU International Ltd., 2001, Aluminium monitor: London, CRU International Ltd., January, p. 8.

Furukawa, Tsukasa, 2000a, Japan firm builds new magnesium recycling facility: American Metal Market, v. 108, no. 192, October 4, p. 10.

———2000b, Japanese company to open US magnesium casting plant: American Metal Market, v. 108, no. 136, July 17, p. 10.

Interfax Mining & Metals Report, 2000a, EBRD to grant Solikamsk Magnesium Plant $95 mln credit: Interfax Mining & Metals Report, v. 9, no. 16, April 14-20, p. 12-13.

———2000b, Uralasbest to add magnesium plant: Interfax Mining & Metals Report, v. 9, no. 15, April 2-13, p. 11.

International Magnesium Association, 2001, Magnesium: McLean, VA, International Magnesium Association, March, 8 p.

Kioke, S., Washizu, K., Nosaka, Y., and Kubota, K., 2000, New creep-resistant magnesium alloy for automobile engine components, *in* IMA 2000, Vancouver, May 21-23, 2000, Proceedings: McLean, VA, International Magnesium Association, p. 15-21.

Light Metal Age, 2000, Aluminum, titanium, magnesium and beryllium are all used in the Saleen supercar: Light Metal Age, v. 58, no. 9-10, October, p. 60.

Metal Bulletin, 2000a, AMC and VAW look to Mg engines for growth: Metal Bulletin, no. 8520, October 26, p. 9.

———2000b, Australian Mg project receives government approvals: Metal Bulletin, no. 8522, November 2, p. 7.

———2000c, Buoyant outlook for Taiwanese magnesium industry: Metal Bulletin, no. 8524, November 9, p. 7.

———2000d, Cassiar moves ahead with magnesium project study: Metal Bulletin, no. 8470, April 27, p. 9.

———2000e, China mulls magnesium smelter closures: Metal Bulletin, no. 8506, September 7, p. 15.

———2000f, CS Aluminium and Hydro in magnesium recycling project: Metal Bulletin, no. 8446, January 31, p. 13.

———2000g, Fresh hopes to revive Ukranian Mg production: Metal Bulletin, no. 8536, December 21, p. 9.

———2000h, Magnesium Elektron finds Czech site for new plant: Metal Bulletin, no. 8501, August 17, p. 9.

———2000i, Magnesium market remains under pressure: Metal Bulletin, no. 8441, January 13, p. 8.

———2000j, Pima raises A$6m for magnesium project: Metal Bulletin, no. 8453, February 24, p. 11.

———2000k, Samag's magnesium plant to be sited at Port Pirie: Metal Bulletin, no. 8478, May 25, p. 8.

———2000l, South Africa tests new Mg production process: Metal Bulletin, no. 8513, October 2, p. 11.

———2001, Workers protest as Pechiney's Mg plant faces closure: Metal Bulletin, no. 8568, April 23, p. 9.

Platt's Metals Week, 2000a, Auction for bankrupt Ningxia: Platt's Metals Week, v. 71, no. 39, September 25, p. 14.

———2000b, China to build magnesium plant: Platt's Metals Week, v. 71, no. 49, December 4, p. 15.

———2000c, Chinese Mg sellers breach reference: Platt's Metals Week, v. 71, no. 22, May 29, p. 7.

———2000d, Dead Sea Magnesium gains Chrysler OK, plans DC startup: Platt's Metals Week, v. 71, no. 12, March 20, p. 9.

———2000e, EU expected to OK Chinese magnesium duty hike: Platt's Metals

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Week, v. 71, no. 20, May 15, p. 11.
———2000f, Israel Chemicals takes over Dead Sea Mg: Platt's Metals Week, v. 71, no. 5, January 31, p. 12.
———2000g, Magnesium recycling project gains partner, plans study: Platt's Metals Week, v. 71, no. 9, February 28, p. 1, 14.
———2000h, Noranda Quebec magnesium plant construction complete: Platt's Metals Week, v. 71, no. 35, August 28, p. 10.
———2000i, Tongxiang halves magnesium output: Platt's Metals Week, v. 71, no. 42, October 16, p. 7.
———2000j, Yinguang Mg line to be done by December: Platt's Metals Week, v. 71, no. 22, May 29, p. 7.
Plunkert, P.A., 2001, Aluminum in March 2001: U.S. Geological Survey Mineral Industry Surveys, May, 7 p.
Revankar, Vithal, Baker, Phillip, Schultz, A.H., and Brandt, Helmut, 2000, A replacement for SF_6—The MagShield system, *in* IMA 2000, Vancouver, May 21-23, 2000, Proceedings: McLean, VA, International Magnesium Association, p. 51-55.
U.S. Department of Commerce, International Trade Administration, 2000a, Initiation of antidumping duty investigations—Pure magnesium from Israel, the Russian Federation, and the People's Republic of China: Federal Register, v. 65, no. 220, November 14, p. 68121-68125.
———2000b, Notice of initiation of countervailing duty investigation—Pure magnesium from Israel: Federal Register, v. 65, no. 220, November 14, p. 68126-68128.
———2000c, Pure magnesium and alloy magnesium from Canada—Final results of countervailing duty administrative reviews: Federal Register, v. 65, no. 175, September 8, p. 54498-54499.
———2000d, Pure magnesium and alloy magnesium from Canada; final results of full sunset reviews reviews [sic] of countervailing duty orders: Federal Register, v. 65, no. 129, July 5, p. 41444-41445.
———2000e, Pure magnesium from Canada; final results of full sunset review: Federal Register, v. 65, no. 129, July 5, p. 41436-41437.
———2001a, Notice of preliminary determination of sales at less than fair value and postponement of final determination—Pure magnesium in granular form from the People's Republic of China: Federal Register, v. 66, no. 83, April 30, p. 21314-21319.
———2001b, Notice of preliminary determination of sales at less than fair value—Pure magnesium from Israel: Federal Register, v. 66, no. 83, April 30, p. 21325-21328.
———2001c, Notice of preliminary determination of sales at not less than fair value—Pure magnesium from the Russian Federation: Federal Register, v. 66, no. 83, April 30, p. 21319-21325.
U.S. International Trade Commission, 2000a, Pure magnesium from China: Federal Register, v. 65, no. 177, September 12, p. 55047-55048.
———2000b, Pure magnesium from Russia: Federal Register, v. 65, no. 137, July 17, p. 44076-44077.
U.S. Environmental Protection Agency, 2000, Agency information collection activities—Proposed collection comment request; reporting and recordkeeping activities associated with EPA's SF_6 emission reduction partnership for the magnesium industry: Federal Register, v. 65, no. 8, January 12, p. 1861-1862.
Wrigley, Al, 2000a, Automakers flash green light to lift magnesium parts use: American Metal Market, v. 108, no. 147, August 1, p. 1, 4.
———2000b, Ford driving magnesium consumption higher: American Metal Market, v. 108, no. 73, April 17, p. 8.
———2000c, Ford shifting to magnesium from plastic for cam covers: American Metal Market, v. 108, no. 160, August 18, p. 3.
———2000d, Ford switching to magnesium for panel support beams: American Metal Market, v. 108, no. 68, April 10, p. 10.
———2000e, GM's crossover vehicles heavy on steel, aluminum: American Metal Market, v. 108, no. 143, July 26, p. 4.
———2000f, Hybrid-electric autos unlikely to hurt steel: American Metal Market, v. 108, no. 214, November 6, p. 12.
———2000g, Magnesium, aluminum gains seen in Ford drive to save gas: American Metal Market, v. 108, no. 151, August 8, p. 15.
———2000h, Meridian building magnesium die-casting facility in Ontario: American Metal Market, v. 108, no. 93, May 5, p. 6.
———2000i, Metal hydride system eyed by GM for electric vehicles: American Metal Market, v. 108, no. 64, April 10, p. 9.
———2000j, Lunt to make magnesium parts for GM: American Metal Market, v. 108, no. 74, April 18, p. 8.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Magnesian Refractories. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Magnesium. Ch. in Mineral Commodity Summaries, annual.
Magnesium. Mineral Industry Surveys, quarterly.
Magnesium. Ch. in Metal Prices in the United States Through 1998, 1999.
Magnesium Recycling in the United States in 1998. Open File Report OF-01-166, 2001, only available at URL http://pubs.usgs.gov/openfile/of01-166

Other

American Metal Market, daily.
International Magnesium Association. Magnesium, monthly.
Magnesium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Magnesium and Magnesite in the CIS in 1996. Roskill Information Services Ltd., 2d ed.
Magnesium Metal. Roskill Information Services Ltd., 7th ed., 1998
Metal Bulletin [London], biweekly.
Platt's Metals Week.

TABLE 1
SALIENT MAGNESIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production:					
Primary magnesium	133,000	125,000	106,000	W	W
Secondary magnesium	71,200	80,200 r/	77,100	86,100 r/	82,300
Exports	40,500	40,500	35,400	29,100	23,800
Imports for consumption	46,600	65,100	82,500	90,700	91,400
Consumption, primary	102,000	100,000	107,000	131,000	104,000
Yearend stocks, producer	17,400	13,100	13,500	W	W
Price per pound 2/	$1.70-$1.80	$1.60-$1.70	$1.52-$1.62	$1.40-$1.55	$1.23-$1.30
World, primary production	378,000 r/	383,000 r/	397,000 r/	342,000 r/	368,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Source: Platt's Metals Week.

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TABLE 2
U.S. MAGNESIUM METAL PRODUCERS, BY LOCATION, RAW MATERIAL, AND PRODUCTION CAPACITY IN 2000

Company	Plant location	Raw material	Annual capacity (metric tons)
Magnesium Corp. of America	Rowley, UT	Lake brines	43,000
Northwest Alloys Inc.	Addy, WA	Dolomite	40,000
Total			83,000

TABLE 3
MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
KIND OF SCRAP		
New scrap:		
Magnesium-base	11,200	12,800
Aluminum-base	40,700 r/	39,400
Total	52,000 r/	52,200
Old scrap:		
Magnesium-base	7,720	7,300
Aluminum-base	26,500 r/	22,800
Total	34,200 r/	30,100
Grand total	86,100 r/	82,300
FORM OF RECOVERY		
Magnesium alloy ingot 2/	W	W
Magnesium alloy castings	5,130	6,870
Magnesium alloy shapes	670	196
Aluminum alloys	68,000 r/	62,400
Zinc and other alloys	2	--
Other 3/	12,300	12,800
Total	86,100 r/	82,300

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
--Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes secondary magnesium content of secondary and primary alloy ingot.
3/ Includes chemical and other dissipative uses and cathodic protection, and data indicated by symbol W.

TABLE 4
U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE 1/

(Metric tons)

Use	1999	2000
For structural products:		
Castings:		
Die	42,600	23,500
Permanent mold	6,100	5,430
Sand	481	527
Wrought products 2/	9,380	2,120
Total	58,600	31,600
For distributive or sacrificial purposes:		
Aluminum alloys	57,800	55,400
Cathodic protection (anodes)	70	98
Chemicals	W	W
Iron and steel desulfurization	9,440	12,200
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	1,730	1,520
Other 3/	3,650	3,570
Total	72,700	72,800
Grand total	131,000	104,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes extrusions, sheet and plate, and forgings.
3/ Includes nodular iron, scavenger, deoxidizer, and powder.

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TABLE 5
U.S. EXPORTS OF MAGNESIUM, BY COUNTRY 1/

Country	Waste and scrap		Metal		Alloys (gross weight)		Powder, sheets, tubing, ribbons, wire, other forms (gross weight)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:								
Canada	16,400	$46,200	785	$2,720	1,850	$5,910	2,220	$8,180
Japan	10	25	564	1,840	88	474	292	2,030
Korea, Republic of	9	40	22	155	83	474	227	616
Mexico	33	87	238	642	94	439	1,200	3,430
Netherlands	5	14	2,340	5,730	20	42	35	203
United Kingdom	--	--	226	763	37	441	719	2,940
Other	43	144	618 r/	2,700 r/	594	3,500	303 r/	2,800 r/
Total	16,500	46,500	4,790	14,600	2,760	11,300	4,990	20,200
2000:								
Canada	6,290	17,100	2,700	7,680	4,930	16,400	957	6,310
Japan	--	--	537	1,740	233	1,520	200	3,400
Korea, Republic of	--	--	12	52	99	506	50	616
Mexico	57	142	31	106	118	686	1,710	5,540
Netherlands	6	14	2,650	7,000	78	166	162	970
United Kingdom	--	--	99	391	29	775	407	1,740
Other	46	195	1,270	3,240	533	3,300	575	5,430
Total	6,400	17,500	7,300	20,200	6,020	23,300	4,060	24,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM, BY COUNTRY 1/

Country	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:								
Brazil	41	$14	120	$307	1,590	$4,390	4	$24
Canada	2,180	3,160	3,920	13,400	32,000	110,000	72	418
China	695	718	--	--	16,300	41,000	--	--
Israel	13	14	11,800	37,400	--	--	169	397
Kazakhstan	--	--	690	1,870	--	--	--	--
Mexico	--	--	61	146	436	1,420	296	1,020
Russia	--	--	10,000	23,800	4,700	15,300	--	--
United Kingdom	455	458	60	406	514	4,250	28	202
Other	3,390	3,330	232	677	988	3,540	25	202
Total	6,780	7,690	26,900	78,000	56,500	180,000	594	2,260
2000:								
Brazil	--	--	450	1,040	(2/)	9	--	--
Canada	6,450	12,800	3,100	10,100	25,700	82,100	1,740	6,710
China	508	548	244	322	21,100	41,800	106	351
Israel	13	6	6,320	18,900	2,110	11,900	--	--
Kazakhstan	--	--	1,340	3,390	--	--	--	--
Mexico	27	50	100	199	328	1,080	431	1,240
Russia	10	10	10,800	23,200	2,610	8,720	(2/)	3
United Kingdom	145	192	(2/)	3	954	5,920	3	237
Other	2,730	2,790	532	1,590	3,550	12,500	22	134
Total	9,890	16,400	22,900	58,700	56,300	164,000	2,300	8,670

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 7
WORLD ANNUAL PRIMARY MAGNESIUM
PRODUCTION CAPACITY, DECEMBER 31, 2000 1/ 2/

(Metric tons)

Country	Capacity
Brazil	12,000
Canada	64,000
China 3/	188,000
France	17,000
India	900
Israel	27,500
Kazakhstan	10,000
Norway	35,000
Russia	40,000
Serbia and Montenegro	5,000
Ukraine	15,000
United States	83,000
Total	497,000

1/ Includes capacity at operating plants, as well as at plants on standby basis.
2/ Data are rounded to no more than three significant digits; may not add to total shown.
3/ Total effective capacity, including many small plants at unknown locations.

TABLE 8
MAGNESIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Primary production:					
Brazil e/	9,000	9,000	9,000	9,000	9,000
Canada e/ 3/	54,000	57,700	77,100	80,000 r/	80,000
China e/	73,100	75,990	70,500	120,000 r/	140,000
France e/	14,000	13,740 4/	14,000	14,000	14,000
Israel	100 r/ e/	7,000 r/	25,000 r/ e/	28,000 r/	34,000
Kazakhstan e/	9,000	8,972 4/	9,000	9,500	9,500
Norway	37,800 r/	34,200 r/	35,400 r/	35,000 r/ e/	35,000
Russia e/ 3/	35,000	39,500	41,500	45,000 r/	45,000
Serbia and Montenegro	2,500 e/	2,500 e/	3,965	1,203	1,200
Ukraine	10,000 e/	10,000 e/	5,043 r/	3 r/	3
United States	133,000	125,000	106,000	W	W
Total	378,000 r/	383,000 r/	397,000 r/	342,000 r/	368,000
Secondary production:					
Brazil e/	1,600	1,600	1,600	1,600	1,600
Japan	8,175	10,934	7,807	7,735 r/	7,800
U.S.S.R. e/ 5/	6,000	NA	NA	NA	NA
United Kingdom e/ 6/	1,000	1,000	1,000	500 r/	500
United States	71,200	80,200	77,100	86,100 r/	82,300 4/
Total	88,000	91,100	87,500	96,000 r/	92,200

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 21, 2001.
3/ Includes secondary.
4/ Reported figure.
5/ Dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual countries of the former U.S.S.R.
6/ Includes alloys.

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MAGNESIUM COMPOUNDS

By Deborah A. Kramer

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Although U.S. production of magnesium compounds in 2000 decreased from that in 1999, apparent consumption increased by about 7%. Production of dead-burned magnesia decreased by about 9%, mainly as a result of the closure of a plant in California, but net imports increased by 36%. Caustic-calcined magnesia production declined by about 4%, and net imports remained about the same. Of the total U.S. magnesium compounds production, about 60% came from seawater and well and lake brines. The remainder was recovered from magnesite, dolomite, olivine, and brucite. About 69% of the total consumption of magnesium compounds was for refractory applications. The remaining 31% was used in agricultural, chemical, environmental, and other applications.

Production

In 2000, domestic production of caustic-calcined magnesia declined slightly from that in 1999. U.S. production of dead-burned magnesia dropped by about 9% from that in 1999, mostly because of the closure of National Refractories and Minerals Corp.'s Moss Landing, CA, plant (table 3).

Data for magnesium compounds were collected by the U.S. Geological Survey from one voluntary survey of U.S. operations. Of the 17 operations canvassed, 71% responded, representing 65% of the magnesium compounds shipped and used (table 3). Data for the five nonrespondents were estimated on the basis of prior-year consumption levels and other factors.

Two companies in the United States produced olivine—Unimin Corp. and Olivine Corp. Unimin operated two mines, one in North Carolina and one in Washington, and processing plants in Indiana, North Carolina, and Washington. Olivine operated one mine and one processing plant in Washington.

Fused magnesia was produced by two companies in the United States—Newminco Inc. with a plant in Midway, TN, and Universal Ceramic Materials plc of the United Kingdom, which operated a plant in Cherokee, AL, through its Muscle Shoals Minerals Inc. subsidiary. The Tennessee plant had been owned by English China Clays International Ltd., which was required to sell the plant when it was acquired by Imerys (formerly Imetal). The plant was sold in June 2000 (Imerys, 2001, Annual report 2000, accessed May 17, 2001, via URL http://www.imerys.com).

The largest magnesite production facilities in the world are in China, North Korea, and Russia. Together, these three countries account for 68% of the world magnesite production capacity. Japan and the United States account for 54% of the world's magnesium compounds production capacity from seawater or brines. Fused magnesia is produced in Australia, Brazil, Canada, China, Israel, Japan, the Republic of Korea,

Magnesium Compounds in the 20th Century

Deposits of magnesite (magnesium carbonate) had been discovered in California in 1886, and by 1910, output of the ore from mines in Santa Clara County had reached 12,000 metric tons per year. Most of the ore was calcined and used by the manufacturers of paper in California and Oregon to treat wood pulp. In 1913, production of magnesia by precipitation of dolomite began in Pennsylvania, and in 1917, mining of magnesite began in Stevens County, WA. Imports of magnesite from Europe, which had been the dominant supplier to the United States, were cut off during World War I. Mining of the magnesite in the Nye County, NV, deposit began in 1937. At the outbreak of World War II, production of magnesian ores in the United States was accelerated to provide material not only for basic refractories but for magnesium metal as well. During World War II, almost 1 million metric tons of magnesite was mined and used to produce magnesium metal. Development of techniques to produce magnesium compounds other than magnesia, however, progressed slowly in the United States. By the end of 1959, more than 13 million tons of magnesite had been taken from the mines in the United States, but the deposits of easily recoverable magnesite in California had been worked out by 1950. In 1956, a broad expansion program began in the basic refractories industry in the United States. This included building new magnesia and basic-brick plants and installing new rotary kilns to burn dolomite, as well as improving and expanding production facilities already in operation. The greatest increase in production capacity was in plants to recover magnesia from seawater and brines. This production, which amounted to less than 40% of total domestic output in 1947, rose gradually to 66% in 1959. Domestic capacity for producing other magnesium compounds continued to increase steadily after World War II. Production of magnesium compounds in the United States peaked in 1966 and trended downward since then as imports replaced domestic production.

By 2000, only one magnesite mine was in operation in the United States in Nye County, NV. Magnesia and other magnesium compounds were produced from seawater at plants in Delaware and Florida, from well brines in Michigan, and from brines from the Great Salt Lake in Utah. Imports of magnesia, mainly from China, supplied about 48% of the total U.S. apparent consumption of magnesium compounds. About 69% of the magnesium compounds consumed in the United States was used for refractories. The remaining 31% was consumed in agricultural, chemical, construction, environmental, and industrial applications. U.S. imports for consumption continued to increase significantly in 2000.

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Mexico, Russia, the United Kingdom, and the United States. World production capacity is estimated to be about 650,000 metric tons per year (t/yr), with about 500,000 t/yr of capacity in China (Pearson, 2000).

Norway is the world's principal producer and supplier of olivine. Other producers include Australia, Italy, Japan, Mexico, Pakistan, Spain, and the United States.

In August 2000, Premier Services Inc. increased the caustic-calcined magnesia capacity at its Gabbs, NV, magnesite facility by 20,000 t/yr to 140,000 t/yr. The capacity increase was in response to growing demand in the wastewater treatment market. About $1 million was spent on an incremental furnace expansion, and Premier Services said that the company may expand further in 2001 if the growth in the market continues (North American Minerals News, 2000c).

Aurora Partners Ltd. of the United States announced that it would form a joint venture with North Korea's Korea Magnesite Clinker Industry Group to mine, process, and ultimately export magnesia products from North Korea. This would be the first joint venture between U.S. and North Korean firms. Although North Korea has been allowed to export magnesite to the United States since 1995, no material has entered since then. An embargo preventing U.S. firms from establishing joint ventures with North Korean companies was lifted in June 2000 (North American Minerals News, 2000a).

Near the end of the year, the State of Utah began modifying the salinity levels in the Great Salt Lake by deepening a causeway opening by more than 2.4 meters (8 feet). The railroad causeway in the lake has been acting as a dam and creating essentially two separate bodies of water with different salinity levels. Deepening the breach in the causeway would allow for greater water flow between the two bodies, thereby equalizing the salinity levels. Although it could be 3 to 5 years before the effects of the causeway modifications are known, this could adversely affect companies that recover magnesium chloride from the higher salinity portion of the Great Salt Lake (Green Markets, 2001).

As part of RHI AG's 1999 acquisition of Global Industrial Technologies Inc., which was the parent company of Harbison-Walker Refractories Inc., RHI was required by the U.S. Federal Trade Commission (FTC) to divest itself of some of its assets. According to a consent agreement, RHI would be required to divest two refractory manufacturing plants in North America as well as assets related to certain refractory products produced at a third North American location. The divestiture was agreed to because, after the merger of RHI and Global, the two companies combined would control about 95% of the $30 million North American market for magnesia-carbon bricks for basic-oxygen furnaces (BOFs) used in the steelmaking industry. In addition, the merged company would hold 65% of the $58 million market for magnesia-carbon bricks for electric-arc furnaces, 40% of the $100 million market for magnesia-carbon bricks for steel ladles used with BOFs, 70% of the $50 million market for high-alumina bricks for steel ladles used with BOFs, 50% of the $23.5 million market for high-alumina bricks for torpedo cars, and 46% of the $5 million market for magnesia-chrome bricks for steel degassers. As a result of its market dominance in these sectors, the FTC ordered RHI to sell to Resco Products Inc. two magnesia-chrome-brick-producing plants (one in Hammond, IN, and one in Marelan, Quebec, Canada) and specific assets related to the production of high-alumina bricks at its Farber, MO, plant. Resco manufactures similar refractory products, but does not compete in the same markets (U.S. Federal Trade Commission, December 30, 1999, FTC clears proposed acquisition of Global Industrial Technologies by RHI AG, accessed March 14, 2001, at URL http://www.ftc.gov/opa/1999/9912/rhi1.htm).

Consumption

In 2000, environmental applications (water treatment and stack gas scrubbing, in descending order) consumed the most caustic-calcined magnesia, accounting for 41% of U.S. shipments; this was a 4% increase from the 1999 total. The following categories, with the individual components in descending order of consumption in parentheses, were the other end-use sectors for caustic-calcined magnesia: chemical, 34%; agriculture (animal feed and fertilizers), 18%; construction (primarily oxychloride and oxysulfate cements), 3%; manufacturing (rubber, fuel additives, and electrical), 3%; pharmaceuticals and nutrition (sugar, medicine and pharmaceuticals, and cosmetics), less than 1%; and unspecified uses, less than 1%.

Magnesium carbonate was used principally as a chemical intermediate, in medicines and pharmaceuticals, in rubber processing, and in cosmetics (uses are given in descending order of quantity). Magnesium hydroxide was used mainly in the chemical industries and for water treatment. Magnesium sulfate was used mostly for animal feed, pulp and paper, chemical, electrical, and pharmaceutical applications. Magnesium chloride was used mainly as a chemical intermediate and in pharmaceuticals. Magnesium chloride brines were used principally for road dust and ice control and as a chemical intermediate.

Foundry uses remained the largest application for olivine in the United States, accounting for 87% of consumption of domestically produced material. Refractory applications accounted for 7% of U.S. consumption, and sandblasting and other abrasive uses accounted for 6%.

Prices

Yearend 2000 prices for magnesium compounds quoted in Chemical Market Reporter and Industrial Minerals remained the same as those for 1999 (table 4).

Foreign Trade

In 2000, dead-burned magnesia exports from the United States declined by about 10% (table 5). Canada, with 85% of the total, was the principal destination. Caustic-calcined magnesia exports, however, increased to nearly four times the 1999 level. Mexico (26%), Japan (19%), Brazil (11%), and the Netherlands (11%) were the main destinations.

U.S. imports of dead-burned magnesia in 2000 increased by 28% from those in 1999 (table 7). China (69%) and Australia (13%) were the principal source countries. One of the reasons for the significant increase in imports was to replace some of the domestically produced material that was lost when National Refractories and Minerals closed its magnesia plant in 1999.

Imports of caustic-calcined magnesia increased by 11% from imports in 1999. China (65%) and Canada (29%) were the primary sources. In spite of the export licensing requirements imposed by the Chinese Government, magnesia exports from

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China to the United States continued to rise. For 2000, the Chinese export quota for magnesite was 1.6 million metric tons (Mt), and the license fee was about $43 per metric ton. Because of falling magnesite prices, many Chinese producers joined to form two separate export syndicates. The producers expected to be able to control prices and export volumes more easily through these syndicates (Industrial Minerals, 2000f).

Trade data for olivine are not available separately from the U.S. Census Bureau. The Journal of Commerce Port Import/Export Reporting Service (PIERS), however, provides data on material that travels by ship. PIERS data indicate that in 2000 the United States exported 871 metric tons (t) of olivine; Argentina (42%), Venezuela (12%), and Brazil (11%) were the principal destinations. U.S. olivine imports totaled 202,000 t, a 73% increase from imports in 1999. Norway (70%) and Poland (28%) were the major source countries.

World Review

Australia.—SAMAG Ltd., the 80%-owned subsidiary of Pima Mining NL, began trial mining of its magnesite deposit in South Australia. The company plans to mine about 2,000 t of ore for trial leaching tests. The company also selected Port Pirie as the site for its proposed 52,500-t/yr magnesium plant. This site was chosen because of its existing infrastructure (the Pasminco zinc smelter is located at the same site), the rail link between Port Pirie, and the location of the magnesite raw material near Leigh Creek. Initial investment in the plant was expected to begin in 2001, with commercial production scheduled for 2004. The company has licensed The Dow Chemical Co.'s electrolytic technology for magnesium production (Metal Bulletin, 2000). SAMAG also purchased the Myrtle Springs and the Huandot magnesite deposits from Unimin Australia Ltd., which increased the company's total magnesite resources in the Leigh Creek, Northern Territory, area to 579 Mt (Pima Mining NL, November 28, 2000, SAMAG purchases additional magnesite resources, accessed January 8, 2001, at URL http://www.pima.com.au/temp.asp?t=asx28nov00).

In October, Mt. Grace Resources NL began bulk magnesite mining operations at its Batchelor magnesium project. The company planned to mine and stockpile 2,000 t of magnesite to provide sample material for test work. An ore parcel was expected to be sent to Mintek in Johannesburg, South Africa, in January for testing (Mt. Grace Resources NL, October 30, 2000, Mt[.] Grace Resources mines ore at Batchelor, accessed November 8, 2000, at URL http://www.mtgrace.com/releases/oct_30_2000.html). Mt. Grace Resources plans to construct a 50,000-t/yr magnesium plant by 2006.

At the end of June, Unimin acquired Normandy Mining Ltd.'s mining assets, which included all its activities under its Commercial Minerals Ltd. subsidiary. Commercial Minerals operates a magnesite mining operation near Myrtle Springs, South Australia (Industrial Minerals, 2000h).

Canada.—Globex Mining Enterprises Inc. acquired the Deloro magnesite deposit after its previous owner, Royal Oak Mines Inc., filed for bankruptcy. Drilling on the property has delineated a resource of more than 100 Mt of ore, containing more than 50% magnesite, 25% to 30% talc, and 16% quartz. The company was reviewing test results conducted in 1991 and was planning to conduct bulk sampling tests before determining how it would develop the deposit (North American Minerals News, 2000b).

China.—For 2001, the quantity of magnesia available for export was the same as it was in 2000—1.6 Mt. The export license fee, however, decreased by approximately $1 per metric ton to $42 per metric ton (Houssa, 2001).

Greece.—Grecian Magnesite S.A. embarked on an investment program designed to improve processing at its operations in Greece and to internationalize the company. As part of its internationalization strategy, Grecian Magnesite acquired 40% of the Spanish holding company Magna Inversiones S.A., which owns the Spanish magnesite producer Magnesitas Navarras S.A. Grecian Magnesite also plans to add two new mineral processing lines that are intended to increase productivity, reduce production costs, and improve the company's environmental protection efforts. The total cost of the acquisition and the production modifications was estimated to be $7 billion, and part of this investment was expected to be financed through stock offering on the Athens Stock Exchange Market (Grecian Magnesite S.A., June 20, 2000, Investment program of Grecian Magnesite S.A., accessed February 12, 2001, at URL http://www.grecianmagnesite.com/Press/pr20062000.html). As part of Grecian Magnesite's modifications, Bateman Project Holdings Ltd. supplied a new 30-metric-ton-per-hour dense-media separation plant to its mine at Yerakini, which was designed to separate waste rock from magnesite.

India.—Almora Magnesite Ltd. was referred to India's Board of Industrial Finance and Reconstruction for assessment of its finances. As a result, the company was looking for foreign investment to develop its magnesite mines and to upgrade its beneficiation plant. Almora Magnesite produced about 50,000 t/yr of crude magnesite and 20,000 t/yr of dead-burned magnesia at its plant in Uttar Pradesh. Competition from imports of Chinese magnesite and a downturn in the domestic steel industry had put financial pressure on India's magnesite producers. In addition, the dead-burned magnesite produced in India has a high silica content, which makes it unsuitable for production of many higher value refractories such as magnesia-carbon brick (Industrial Minerals, 2000a).

Israel.—Dead Sea Periclase Ltd. announced that it would increase magnesium hydroxide production capacity at its Mishor Rotem plant to 9,000 t/yr, a 3,000-t/yr increase. The first phase of the two-phase expansion was completed in September; the remaining capacity was expected to be completed by early 2001. The company was increasing its capacity because of a successful audit from the country's Food and Drug Administration. The successful audit was expected to increase demand for the company's magnesium hydroxide from the food and pharmaceutical industry (Chemical Week, 2000).

Jordan.— Jordan Magnesia Co. received a $30-million loan from a syndicate of banks, which would allow it to proceed with construction of its planned magnesia plant. The company already had received $28 million from the Islamic Development Bank and the Islamic Portfolio. The total cost of the plant was estimated to be $101 million. Plant commissioning was scheduled for the beginning of 2001, and the annual plant capacity will be 50,000 t of dead-burned magnesia and 10,000 t of specialty magnesium compounds. About 489,000 cubic meters per year of magnesium chloride-rich brine from Arab Potash Co.'s existing solar ponds and 165,000 t/yr of limestone mined from a quarry at nearby Qatrana will supply the plant's feedstock (Fertilizer International, 2000).

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Russia.—After celebrating a century of mining in September and extracting its 200 millionth metric ton of ore from the Satka magnesite deposits in August, JSC Kombinat Magnezit announced plans to improve its magnesite mining and processing operations. Magnezit operated two open pit mines, one underground mine, and two beneficiation plants with a capacity to produce about 2.5 Mt of magnesia products annually. The company planned to construct a briquetting and processing plant that can use dust from its magnesite beneficiation operation as feed material. The company also acquired the mining rights to the Goluboe magnesite deposit, which has reserves of 6 Mt, including 2 Mt of magnesite containing 45% MgO. Magnezit planned to construct a fused magnesia plant using magnesite from the Goluboe deposit as feed material. Magnezit also planned to prolong the life of its open pit mines by mining more ore from its underground mine (Industrial Minerals, 2000d, e).

Magnitogorsk Iron and Steel Works, one of Russia's largest steel producers, commissioned a new magnesia-dolomite refractories plant in 2000. The first stage of the new operation, with a capacity of 12,000 t/yr, began producing magnesia-carbon bricks to replace refractories previously purchased from Magnezit. The second stage was expected to add 18,000 t/yr of dolomite refractories production to the plant. Total cost of the project was estimated to be $40 million. When the plant is completed, Magnitogorsk will be able to supply about 70% of its refractories needs with material produced in-house (Industrial Minerals, 2000g).

Turkey.—In May, Austria's Styromagnesit Steirische Magnesitindustrie GmbH (Styromag) purchased Comag Continental Mining Industry & Trade Co. Inc. The purchase included Comag's mine and plants in Middle Anatolia, Turkey, with a capacity of 50,000 t/yr of caustic-calcined magnesite, that had been shut since March. Styromag planned to restart the operation in July under the name Calmag. Previously, much of the operation's production had been used for animal feed, but Styromag wanted to concentrate on sales of fused magnesia. The acquisition would also broaden Styromag's product line of caustic-calcined magnesia products—Styromag produced crystalline magnesite at its Austrian operation, and the Calmag operation produced cryptocrystalline magnesite (Industrial Minerals, 2000i).

The Turkish refractories producer Haznedar Ates Tugla Sanayii A.S. planned to begin production in early 2001 at a new refractories operation in Istanbul. The new plant will replace an old 30,000-t/yr operation producing magnesia-carbon and alumina bricks. The new plant, which will produce about 50,000 to 60,000 t/yr of high-density alumina and magnesia bricks, will incorporate some of the old equipment into the new facility. The company hoped to improve product quality. About 75% of the refractories were used locally, and the rest were exported to neighboring countries (Industrial Minerals, 2000c).

Current Research and Technology

Krosaki Harima Corp. developed a new brand of refractory product that was considered to be more environmentally friendly than traditional refractories. In the alumina monolithics that the company produced, it replaced the Cr_2O_3 with MgO. Replacing the Cr_2O_3 with MgO eliminates the generation of hexavalent chromium, which can lead to environmental problems when discarding the refractories (Industrial Minerals, 2000b).

Outlook

Because the primary use of refractory magnesia is in iron and steel production furnaces, economic factors that influence the production of iron and steel will have a direct effect on the consumption of refractory magnesia. According to the International Iron and Steel Institute, the North American steel industry is concerned about higher energy prices and increased levels of imports (International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth, accessed April 16, 2001, at URL http://www.worldsteel.org/trends_indicators/demand.html). If energy costs remain high or increase, it could lead to closure of some North American steel production capacity. This, in turn, could lead to higher levels of imports, which would be required to supply the steel demand. Also, if the U.S. economy becomes stagnant or enters a recession, the total demand for steel is likely to decline as well. A decline in steel demand coupled with closure of U.S. capacity would lead to a significantly reduced demand for refractory magnesia.

Imports of magnesite, mainly from China, are expected to continue to supply much of the U.S. demand for magnesia for refractory applications. If material from North Korea becomes available on the U.S. market, it would probably provide an additional source of low-cost magnesia to U.S. refractories manufacturers at the expense of domestically produced material. Consumption of caustic-calcined magnesia, however, is expected to continue to be strong. Because it has such diverse applications, a decline in one particular industry sector is not as devastating as a drop in steel production is to the refractory magnesia industry. Such environmental applications as wastewater treatment are expected to continue to be the principal growth area for caustic-calcined magnesia.

References Cited

Chemical Week, 2000, Dead Sea Periclase adds magnesium hydroxide: Chemical Week, v. 162, no. 31, August 16, p. 24.

Fertilizer International, 2000, Middle East magnesium projects gain pace: Fertilizer International, no. 375, March-April, p. 13.

Green Markets, 2001, Great Salt Lake dredging finishes with eye on balancing salinity: Green Markets, v. 25, no. 2, January 8, p. 10-11.

Houssa, Charles-Etienne, 2001, Magnesia prices under the spotlight: Mineral PriceWatch, no. 75, March, p. 10-12.

Industrial Minerals, 2000a, Almora seeks help to save MgO business: Industrial Minerals, no. 394, July, p. 15.

———2000b, Harima MgO monolithics: Industrial Minerals, no. 391, April, p. 72.

———2000c, Haznedar expands new refractories plant: Industrial Minerals, no. 398, November, p. 16.

———2000d, Kombinat Magnezit completes a century: Industrial Minerals, no. 391, April, p. 15.

———2000e, Magnezit develops magnesite for fused MgO: Industrial Minerals, no. 399, December, p. 26.

———2000f, $MgCO_3$ producers form export syndicates: Industrial Minerals, no. 393, June, p. 9, 12.

———2000g, Refractories plant commissioned at Magnitogorsk: Industrial Minerals, no. 399, December, p. 26.

———2000h, Sibelco hits minerals market with double whammy: Industrial Minerals, no. 395, August, p. 8-9.

———2000i, Styromag buys Turkey's Comag: Industrial Minerals, no. 395, August, p. 9-10.

Metal Bulletin, 2000, Samag's magnesium plant to be sited at Port Pirie: Metal Bulletin, no. 8478, May 25, p. 8.

North American Minerals News, 2000a, First for US as Aurora signs North Korea magnesia agreement: North American Minerals News, no. 65,

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October, p. 7.
———2000b, Globex sees bright future for acquired magnesite deposit: North American Minerals News, no. 59, April, p. 5.
———2000c, Premier completes $1m. caustic magnesia expansion: North American Minerals News, no. 64, September, p. 6.
Pearson, Karine, 2000, Feeling the Chinese burn: Industrial Minerals, no. 392, May, p. 21-33.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Magnesian Refractories. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Magnesium Compounds. Ch. in Mineral Commodity Summaries, annual.

Other

Chemical Market Reporter, weekly.
Industrial Minerals (London), monthly.
Magnesite and magnesia. Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Magnesium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Magnesium and magnesite in the CIS. Roskill Information Services Ltd., 2d ed., 1996.
Magnesium compounds and chemicals. Roskill Information Services Ltd., 8th ed., 1997.
Olivine. North American Minerals News (London), monthly, 2d ed., Roskill Information Services Ltd., 1990.

TABLE 1
SALIENT MAGNESIUM COMPOUND STATISTICS 1/

(Thousand metric tons, unless otherwise specified)

		1996	1997	1998	1999	2000
United States:						
Caustic-calcined and specified magnesias: 2/						
Shipped by producers: 3/						
Quantity		158	160	177	179	172
Value	thousands	$47,600	$52,600	$76,700	$77,000	$46,000
Exports 4/		20	5	5	3	12
Imports for consumption 4/		114	133	127	123	136
Refractory magnesia:						
Shipped by producers: 3/						
Quantity		269	283	215	216	196
Value	thousands	$96,800	$97,500	$75,000	$75,300	$68,100
Exports		73	66	63	67	60
Imports for consumption		271	279	427	392	501
World production (magnesite)		11,000	10,400	11,800 r/	10,500 r/	10,700 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Excludes caustic-calcined magnesia used in the production of refractory magnesia.
3/ Includes magnesia used by producers.
4/ Caustic-calcined magnesia only.

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TABLE 2
U.S. MAGNESIUM COMPOUND PRODUCERS, BY RAW MATERIAL SOURCE, LOCATION, AND PRODUCTION CAPACITY, IN 2000

Raw material source and producing company	Location	Capacity (metric tons of MgO equivalent) 1/	Products
Brucite: Applied Chemical Magnesias Corp.	Van Horn, TX; and Bullhead City, AZ	25,000	Magnesium hydroxide.
Magnesite: Premier Services Inc.	Gabbs, NV	140,000	Caustic-calcined and dead-burned magnesia.
Lake brines:			
IMC Kalium Ogden Corp.	Ogden, UT	105,700	Magnesium chloride and magnesium chloride brines.
Reilly Industries Inc.	Wendover, UT	45,000	Magnesium chloride brines.
Well brines:			
The Dow Chemical Co. 2/	Ludington, MI	214,000	Magnesium hydroxide.
Martin Marietta Magnesia Specialties Inc. 3/	Manistee, MI	297,000	Caustic-calcined and dead-burned magnesia.
Rohm and Haas Co.	do.	10,000	Magnesium carbonate, magnesium hydroxide, and caustic-calcined magnesia.
Seawater:			
Barcroft Co.	Lewes, DE	5,000	Magnesium hydroxide.
Premier Services Inc.	Port St. Joe, FL	50,000	Caustic-calcined magnesia and magnesium hydroxide.
Western Salt Co.	Chula Vista, CA	3,000	Magnesium chloride brines.
Total		894,700	

1/ Data are rounded to no more than three significant digits; may not add to total shown.
2/ Most of Dow's production was shipped to RHI Refractories America Inc. in Ludington, MI, where it was converted to dead-burned magnesia at a 200,000-metric-ton-per-year plant.
3/ In addition to its Michigan plant, Martin Marietta owned a 30,000-metric-ton-per-year magnesium hydroxide plant in Pittsburgh, PA, and a 15,000-metric-ton-per-year magnesium hydroxide plant in Lenoir City, TN, which used imported magnesite as a raw material.

TABLE 3
U.S. MAGNESIUM COMPOUNDS SHIPPED AND USED 1/

	1999		2000	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined and specified (USP and technical) magnesias 2/	179,000	$77,000	172,000	$46,000
Magnesium hydroxide [100% Mg(OH)2] 2/	233,000	44,100	212,000	81,700
Magnesium sulfate (anhydrous and hydrous)	47,100	14,500	44,000	12,700
Precipitated magnesium carbonate 2/	2,190	4,890	1,960	4,650
Refractory magnesia	216,000	75,300	196,000	68,100

1/ Data are rounded to no more than three significant digits.
2/ Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

TABLE 4
YEAREND MAGNESIUM COMPOUND PRICES

Material		1999	2000
Magnesia, natural, technical, heavy, 85%, f.o.b. Nevada	per short ton	$232-$265	$232-$265
Magnesia, natural, technical, heavy, 90%, f.o.b. Nevada	do.	265	265
Magnesia, dead-burned	do.	350	350
Magnesia, synthetic, technical	do.	385	385
Magnesium chloride, hydrous, 99%, flake	do.	290	290
Magnesium carbonate, light, technical, freight equalized	per pound	0.73-0.78	0.73-0.78
Magnesium hydroxide	do.	0.45	0.45
Magnesium sulfate, technical, epsom salts	do.	0.18-0.195	0.18-0.195
Olivine, aggregate, f.o.b. plant or mine	per metric ton	50-78	50-78
Olivine, foundry grade, f.o.b. plant or mine	do.	60-110	60-110

Sources: Chemical Market Reporter and Industrial Minerals.

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TABLE 5
U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY 1/

Material and country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Caustic-calcined magnesia:				
Brazil	122	$126	2,170	$2,980
France	95	42	1,080	525
Germany	689	339	748	405
Japan	--	--	1,310	1,750
Mexico	1,220	613	3,020	983
Netherlands	573	294	1,280	717
Other	492 r/	265 r/	2,000	1,110
Total	3,190	1,680	11,600	8,470
Dead-burned and fused magnesia:				
Canada	51,800	15,700	50,300	14,800
Hong Kong	176	213	1,650	1,920
Korea, Republic of	998	543	2,140	1,570
Mexico	690	339	429	231
Netherlands	6,460	2,100	622	265
Philippines	2,000	600	--	--
United Kingdom	1,380	3,140	181	351
Other	3,270 r/	2,620 r/	4,500	3,310
Total	66,700	25,200	59,800	22,400
Other magnesia:				
Canada	5,180	$2,040	5,090	$1,950
Hong Kong	1,580	1,900	775	1,020
Mexico	4,790	4,590	5,610	4,680
New Zealand	146	217	2,120	1,980
Spain	961	1,080	671	812
Taiwan	454	254	245	218
Venezuela	2	25	2,670	712
Other	2,660 r/	3,230 r/	4,230	7,590
Total	15,800	13,300	21,400	19,000
Crude magnesite:				
Brazil	1,140	129	2,870	306
Canada	3,490	540	3,520	504
Germany	6,520	796	5,740	621
Korea, Republic of	4,500	512	1,250	136
Mexico	6,140	699	2,750	311
Netherlands	740	79	3,130	424
Spain	168	25	2,960	316
Venezuela	2,950	323	2,100	239
Other	3,220 r/	419 r/	5,180	601
Total	28,900	3,520	29,500	3,460

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. EXPORTS OF MAGNESIUM COMPOUNDS 1/

Material	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)	Principal destinations, 2000
Magnesium chloride, anhydrous and other	4,420	$2,310	4,900	$15,800	Canada, 79%; India, 14%.
Magnesium hydroxide and peroxide	18,900	7,540	20,200	10,600	Canada, 70%.
Magnesium sulfate, natural kieserite and epsom salts	393	210	453	224	Honduras, 44%; Ireland, 27%.
Magnesium sulfate, other	5,140	2,260	6,200	2,970	Canada, 87%.

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY 1/

Material and country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Caustic-calcined magnesia:				
Canada	43,100	$7,630	38,700	$6,760
China	71,500	7,650	88,500	9,940
Greece	5,080	1,220	5,000	1,200
Other	2,950	2,590	4,070	4,170
Total	123,000	19,100	136,000	22,100
Dead-burned and fused magnesia:				
Australia	45,400	11,900	65,900	14,800
Austria	19,800	11,400	21,500	9,860
Brazil	15,500	2,790	10,000	990
China	275,000	34,900	345,000	44,600
Greece	7,740	1,340	3,030	558
Hong Kong	4,000	368	18,300	2,280
Israel	3,400	4,000	9,820	7,220
Other	21,400	8,360	27,100	7,860
Total	392,000	75,000	501,000	88,200
Other magnesia:				
Canada	4,550	925	6,250	1,180
China	1,670	832	275	209
Israel	4,330	7,190	2,870	5,130
Japan	1,670	2,880	1,680	3,150
Mexico	3,440	1,930	4,700	2,270
Other	2,230	1,100	3,130	2,200
Total	17,900	14,900	18,900	14,100
Crude magnesite:				
China	4,080	708	6,010	776
Israel	639	203	979	202
Japan	962	212	2,530	558
United Kingdom	1,210	291	3,520	953
Other	1,010 r/	305 r/	1,540	337
Total	7,900	1,720	14,600	2,830

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM COMPOUNDS 1/

	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)	Principal sources, 2000
Magnesium chloride, anhydrous and other	24,500	$5,600	35,800	$7,210	Israel, 91%.
Magnesium hydroxide and peroxide	7,440	12,600	8,960	14,700	Japan, 35%; Israel, 28%; Netherlands, 12%.
Magnesium sulfate, natural epsom salts	82	64	85	23	Germany, 90%.
Magnesium sulfate, natural kieserite	23,800	595	27,000	831	Germany, 100%.
Magnesium sulfate, other	26,700	5,170	31,800	7,030	Germany, 56%; Canada, 33%.

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 9
WORLD MAGNESIUM COMPOUNDS ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 2000 1/ 2/

(Thousand metric tons, MgO equivalent)

Country	Raw material				Total
	Magnesite		Seawater or brines		
	Caustic-calcined	Dead-burned	Caustic-calcined	Dead-burned	
North America:					
Canada	100	--	--	--	100
Mexico	--	--	20	95	115
United States	NA	NA	NA	NA	895 3/
Total	100	NA	20	95	1,110
South America, Brazil	58	276	--	--	334
Europe:					
Austria	35	250	--	--	285
France	--	--	30	--	30
Greece	120	80	--	--	200
Ireland	--	--	--	90	90
Italy	25	--	5	130	160
Netherlands	--	--	--	150	150
Norway	--	--	25	--	25
Poland	--	10	--	--	10
Russia	100	2,670	--	--	2,770
Serbia and Montenegro	40	200	--	--	240
Slovakia	--	440	--	--	440
Spain	155	60	--	--	215
Turkey	50	324	--	--	374
Ukraine	--	120	20	80	220
United Kingdom	--	--	70	80	150
Total	525	4,160	150	530	5,360
Africa:					
Kenya	NA	NA	--	--	170
South Africa	7	--	--	--	7
Total	7	NA	--	--	177
Asia:					
China	200	2,480	--	10	2,690
India	25	257	--	--	282
Iran	--	30	--	--	30
Israel	--	--	10	60	70
Japan	--	--	65	265	330
Korea, North	--	500	--	--	500
Korea, Republic of	--	--	--	50	50
Total	225	3,260	75	385	3,950
Oceania, Australia	48	120	--	--	168
Grand total	963	7,810	245	1,010	11,100

NA Not available. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes capacity at operating plants, as well as at plants on standby basis.

3/ Includes capacity for production of magnesium chloride, magnesium chloride brines, magnesium carbonate, magnesium hydroxide, and caustic-calcined and dead-burned magnesias.

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TABLE 10
MAGNESITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Australia	237,707	245,192	360,115 r/	280,505 r/	349,783 3/
Austria	624,000	650,000 e/	723,000 r/	769,000 r/	750,000
Brazil (beneficiated) 4/	305,737	294,629	308,300	310,000 e/	310,000
Canada e/ 5/	180,000	180,000	180,000	180,000	180,000
China e/	2,100,000	2,400,000	2,400,000	2,450,000	2,500,000
Colombia e/	12,634 r/ 3/	10,500	10,500	10,500	10,500
Greece	682,346	623,050	650,000 e/	650,000 e/	650,000
India	373,306	362,929	355,033	360,000 e/	365,000
Iran 6/	55,000 r/ e/	55,000 r/ e/	109,597 r/	141,081 r/	141,000
Korea, North e/	1,600,000	1,600,000	1,600,000	1,000,000	1,000,000
Mexico	200	231	274	308 r/	335 3/
Pakistan	3,202	4,057	3,157	3,000 e/	3,100
Philippines e/	700	700	700	700	700
Poland	19,300	6,403	5,745	6,000 e/	--
Russia e/	1,000,000	1,040,000	851,845 3/	900,000	1,000,000
Serbia and Montenegro	89,000	95,000	81,000 r/	22,000 r/	40,000
Slovakia	824,800	863,600	877,840	850,000 e/	850,000
South Africa	71,358	76,669	74,300	74,000 r/	74,000
Spain e/	483,726 3/	500,000	500,000	500,000	500,000
Turkey (run of mine)	2,339,138	1,409,768	2,703,343	2,000,000 r/ e/	2,000,000
United States	W	W	W	W	W
Zimbabwe	10,659	13,050	4,321	4,000 e/	4,000
Total	11,000,000	10,400,000	11,800,000 r/	10,500,000 r/	10,700,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 18, 2001.

3/ Reported figure.

4/ Series reflect output of marketable concentrates. Production of crude ore was as follows, in tons: 1996--1,268,265; 1997--1,030,171; and 1998-2000--1,050,000 (estimated).

5/ Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

6/ Year beginning March 21 of that stated.

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MANGANESE

By Thomas S. Jones

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

Manganese (Mn) is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Steelmaking, including its ironmaking component, has accounted for most domestic manganese demand, presently in the range of 85% to 90% of the total demand. Among a variety of other uses, manganese is a key component of certain widely used aluminum alloys and is used in oxide form in dry cell batteries. The overall level and nature of manganese use in the United States is expected to remain about the same in the near term. No practical technologies exist for replacing manganese with other materials nor for utilizing domestic deposits or other accumulations in order to reduce the complete dependence of the United States on foreign countries for manganese ore.

Domestic consumption of manganese ore, exclusive of the relatively small quantities used at iron and steel plants, increased marginally, and was just slightly less than the average consumption for the prior 4 years. Unit consumption of manganese in steel, as ferroalloys and metal, was 6 kilograms per metric ton (kg/t) of raw steel produced, as estimated from apparent consumption calculations. This level also was about the same as the average for the prior 4 years.

For U.S. foreign trade in manganese materials, volumes generally decreased for exports and increased for imports. On a content basis, the number of manganese units imported increased by about 9%, while the number of units exported declined by about 14%. The volume of receipts reached new record levels for manganese dioxide (third successive year) and silicomanganese.

Prices reversed the trend of 1999 and increased for ore and ferroalloys. The amount of increase was about 7% internationally for metallurgical-grade ore; and, for imported ferroalloys on a year-average basis, 6% for high-carbon ferromanganese, 23% for medium-carbon ferromanganese, and 8% for silicomanganese. In 2000, ferroalloy prices were at their highest in the first half of the year. Sales of manganese materials from the Government's National Defense Stockpile reduced the Government's inventory of manganese by about another 5%, leaving an inventory about 1.5 times annual domestic consumption. The larger disposals were of high-carbon ferromanganese and metallurgical-grade ore.

World production of manganese ore was estimated to have increased about 11% (contained weight) in comparison with that for 1999. (See table 1.) China was assumed to be the largest producer on a gross weight basis; South Africa easily was the largest producer on a contained weight basis. A number of the larger ferroalloy producers revamped their operations, such as those in Brazil, France, and South Africa. In Ukraine, production of ore and ferroalloys increased significantly.

Most data in this report are rounded by the U.S. Geological Survey (USGS) to not more than three significant digits. Table footnotes indicate which statistics have been rounded.

Legislation and Government Programs

Stockpile.—The proposed Annual Materials Plan (AMP) for fiscal year 2001 that the Defense National Stockpile Center (DNSC) of the Defense Logistics Agency issued on October 3 was the same with respect to manganese as in the AMPs that were in effect for fiscal years 1999 and 2000. The AMP for

Manganese in the 20th Century

In the early 1900s, annual domestic apparent consumption of manganese was in the range of 100,000 to 200,000 metric tons. Annual ore consumption was about 100,000 tons, of which approximately 90% was derived from imported ore. World production of ore was in the range of 1 to 2 million metric tons. Domestic ore production, which virtually had ceased by 1970, mostly had been as manganiferous ore such as that coproduced with iron ore. At the close of the century, annual domestic apparent consumption of manganese was about 750,000 tons valued at approximately $400 million. World output of ore was approximately 20 million tons per year.

Manganese demand had been driven mainly by steel production, which typically accounted for 85% to 95% of total manganese demand. The importance of manganese to steel production and the lack of domestic production led to the establishment of a number of Government programs to ensure manganese supply, including buildup of sizable inventories, particularly beginning in the 1950s. The trend in manganese demand in steelmaking was displaced downwards beginning about 1980 because of changes in steelmaking technology.

Domestically, ore was smelted to ferromanganese mainly in blast furnaces until the late 1970s. The last remaining domestic ferromanganese producer used electric furnace production for manganese ferroalloys, a process whose early usage was spurred by World War I. Manganese metal and dioxide were developed as electrolytic products in the 1930s and 1940s. Research by the former U.S. Bureau of Mines contributed importantly to commercialization of electrolytic methods for producing manganese metal and dioxide. Electrolytic manganese dioxide became a key ingredient in household batteries, and the demand for it had the highest growth rate of any manganese commodity product.

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fiscal year 2001 became effective as of October 1, 2000, the start of the 2001 fiscal year. Under this AMP, the maximum disposal authority for manganese materials was 27,216 metric tons (t) for natural battery-grade ore; 2,732 t for synthetic manganese dioxide; 36,287 t for chemical-grade ore; 226,796 t for metallurgical-grade ore; 45,359 t for the manganese ferro group; and 1,814 t for electrolytic manganese metal.

In its sales program for metal, the DNSC amended as of October 1 its Solicitation of Offers DLA-ELECTROLYTIC MANGANESE METAL-001 so as to make available the same quantity of metal; 1,814 t, as in the AMP. When originally issued on May 1, 1997, the quantity of metal being made available was 1,053 t.

For 2000, disposals of manganese materials announced by the DNSC totaled 5,988 t for natural battery-grade ore; 6,565 t for chemical-grade ore; 37,987 t for stockpile-grade metallurgical-grade ore; 90,719 t for high-carbon ferromanganese; and 146 t for electrolytic metal. All disposals were cash transactions.

Data on physical inventory of manganese materials reported by the DNSC indicated that all net changes in 2000 were decreases and consisted of 5,928 t for natural battery-grade ore, 3,600 t for chemical-grade ore, 52,060 t for stockpile-grade metallurgical-grade ore, 923 t for nonstockpile-grade metallurgical-grade ore, and 32,524 t for high-carbon ferromanganese. The estimated manganese content of manganese inventories being held by the Government at yearend was lowered in 2000 by about another 5%, to somewhat greater than 1.1 million metric tons (Mt). (See table 2.) The total remaining inventory was about 1.5 times current national apparent consumption.

Other.—In August, the Drug Enforcement Administration of the U.S. Department of Justice sustained its 1998 suspensions of three shipments of Chinese potassium permanganate that were to have been transshipped to Colombia through ports in California. These shipments were suspended because of the possibility that they might be diverted for use in the manufacture of cocaine (Drug Enforcement Administration, 2000).

In November, the Agency for Toxic Substances and Disease Registry of the U.S. Department of Health and Human Services announced that six updated final toxicological profiles for priority hazardous substances had become available (Agency for Toxic Substances and Disease Registry, 2000). One of these, Toxicological Profile for Manganese, emphasized the health effects of manganese and related toxicological information (Sciences International, Inc., 2000).

As of December 26, the Employment and Training Administration (ETA) of the U.S. Department of Labor certified that specified current and former workers at the North Plant of Eramet Marietta Inc., Marietta, OH, were eligible to apply for benefits under the Trade Adjustment Assistance (TAA) program administered by ETA. This determination was made after Eramet Marietta had notified the ETA that it had accepted delivery of imported manganese metal in place of its own production (Employment and Training Administration, 2001). Shortly before that, the ETA had determined that these workers were not eligible to apply for such assistance (Employment and Training Administration, 2000). Under the TAA program, workers whose jobs are adversely affected by increased imports can receive various benefits and services designed to help them obtain suitable employment.

Production

Ore and Concentrate.—The only possible mine production of manganese consisted of small amounts of manganiferous material having a natural manganese content of less than 5%. This type of material has been produced in South Carolina for use in coloring brick.

Ferroalloys, Metal, and Synthetic Dioxide.—Production statistics for these materials were not published to avoid disclosing proprietary data. The only plant at which manganese ferroalloys were produced domestically was that of Eramet Marietta at Marietta, OH (table 3). In July, Eramet Marietta announced that by the end of the year it would close its facilities for producing manganese metal. Production of metal was a minor part of that plant's overall production program that included an annual output of about 170,000 t of manganese ferroalloys. Production of manganese-aluminum briquets for use as aluminum hardeners was to continue using manganese not produced at Marietta (Platt's Metals Week, 2000).

Consumption, Uses, and Stocks

Data relating to manganese end use and certain other information have indicated that metallurgical applications account for most domestic manganese consumption, 85% to 90% of which has been for steelmaking. This usage pattern is typical for most industrialized countries (Mining Magazine, 1990). Reported data for U.S. ore consumption in 2000 indicated that unit consumption of manganese in ironmaking, which could not be published to avoid disclosing proprietary data, declined from that for 1999 to become an even smaller comparatively minor component of overall manganese use in steelmaking. Reported data for U.S. consumption of manganese ferroalloys and metal in 2000 are presented in table 4. Data in this table are not directly comparable to those for years prior to 1998, especially for ferromanganese. Also, because of the incompleteness of reporting to the USGS's voluntary consumption survey, the figures in this table are more representative of relative rather than absolute quantities. Combination of the indicated consumption pattern with estimates of apparent consumption suggests that manganese unit consumption in steelmaking in 2000 was about 6 kg/t or about twice that if calculated on the basis of reported consumption. Overall domestic manganese apparent consumption in 2000 was estimated as 774,000 t.

In decreasing order, the most important steel end uses in the United States were given as construction, automotive, machinery, and domestic and commercial equipment (Iron & Steelmaker, 2000).

Ownership of plants for manufacture of manganese sulfide used, for example, in parts made by iron powder metallurgy, were included in the sale of the Pyron Corp. and Pyron Metals Powders, Inc., subsidiaries of Zemex Corp., Toronto, Canada, to Sweden's Höganäs AB. Plants involved in the sale were located in New York, Pennsylvania, and Tennessee (Skillings Mining Review, 2000).

Relatively small quantities of manganese were used for alloying with nonferrous metals, chiefly in the aluminum industry as manganese-aluminum briquets that typically

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contained either 75% or 85% manganese. The small addition to manganese demand from the U.S. Mint's introduction in 1999 of the so-called Golden Dollar was diminished because of the new coin's lack of popularity (Day, 2001).

In 2000, domestic consumption of manganese ore increased by a marginal amount to 486,000 t, while corresponding yearend stocks increased by about 31% to 226,000 t. Because of the need to avoid disclosing proprietary data, these figures do not include the relatively small quantities associated with ironmaking and cannot be disaggregated into end-use segments.

Comparatively small amounts of manganese were used domestically in animal feed, brick coloring, dry cell batteries, manganese chemicals, and fertilizers. These were among the many nonmetallurgical applications of manganese (Weiss, 1977; Harben, Raleigh, and Harris, 1998). The source of manganese units for these applications was mainly manganese ore. As discussed under Spain in the World Review section of this report, Carus Chemical Co., Peru, IL, the only domestic producer of potassium permanganate, completed its acquisition of the only Spanish maker of that chemical. Remediation of sites such as those of Government facilities that have been contaminated with chlorinated solvents was a growing application for potassium permanganate (Wickramanayake, Gavaskar, and Chen, 2000a, b). In December, TETRA Technologies, Inc., headquartered in The Woodlands, TX, in exiting the micronutrients business, sold all of its U.S. and foreign manganese sulfate assets (TETRA Technologies, 2001, p. 15). TETRA had been producing manganese sulfate at plants at Fairbury, NE, and in Mexico. Sale of the Mexican plant is discussed under Mexico in the World Review section of this report.

Data on domestic consumption of manganese ore, exclusive of that consumed within the steel industry, are collected by means of the Manganese Ore and Products survey. Approximately 15 firms were canvassed that process ore by such methods as grinding and roasting or that consume it in the manufacture of dry cell batteries and manganese ferroalloys, metal, and chemicals. The collective consumption of these firms is believed to constitute all manganese ore consumption in the United States, exclusive of that by the steel industry. Full-year responses, or a basis upon which to estimate the data, were obtained from all these firms for 2000.

In batteries containing manganese, those of the alkaline type in which electrolytic manganese dioxide (EMD) is used continued to expand their share of the market at the expense of those of the carbon-zinc type in which natural battery-grade ore is a component. Market penetration of alkaline batteries in 2000 was 91% for North America, 62% for Europe, 32% for Latin America, and 26% for Asia. New products were aimed at applications requiring a high discharge rate, such as in digital cameras. Battery sales in 2000 were depressed by the abnormally high sales in the last quarter of 1999 that were brought on by anticipation of Y2K problems (MacArthur and Blomgren, 2001, p. 35-37). In military applications, lithium-sulfur dioxide batteries were being replaced mostly by those of the lithium-manganese dioxide type (Advanced Battery Technology, 2000).

In April, the battery products business of Ralston Purina Co. was spun off into Energizer Holdings, Inc., an independent company, that included the Eveready Battery Co., one of the principal domestic battery makers (Haflich, 2000). Ralston Purina and Energizer were headquartered in St. Louis, MO.

Recycling of batteries such as dry cells, a topic of considerable interest in Western Europe, has led to development of a variety of processes for recovering metals or removing them from the environment. A hydrometallurgical process developed in France recovers manganese as the carbonate or sulfate (Ferlay and Weill, 2000).

Prices

For 2000, if the price of manganese in metallurgical-grade ore is set at 1.0, the corresponding price per manganese unit was approximately 2.6 for high-carbon ferromanganese, 4.2 for medium-carbon ferromanganese, 2.5 for silicomanganese, and 7.5 for manganese metal. Compared with the corresponding price factors for 1999, the factor for high-carbon ferromanganese was unchanged, while those for medium-carbon ferromanganese and silicomanganese are somewhat greater. The factors are based on year-average prices for ferroalloys as derived from prices listed in Platt's Metals Week, and for metal as given in Ryan's Notes (North American transaction price). Year-average prices increased for metallurgical-grade ore and all main categories of manganese ferroalloys.

Manganese Ore.—The average price, on the basis of cost, insurance, and freight (c.i.f.) U.S. ports, of metallurgical-grade ore containing 48% manganese was assessed at $2.39 per metric ton unit. It is recognized that prices were somewhat above or below this value, depending on ore quality, time of year, and nature of the transaction. The price of a metric ton of ore is obtained by multiplying the metric ton unit price by the percentage manganese content of the ore; that is, by 48 when the manganese content is 48%. The ore market consisted of a number of submarkets because of differences between ores according to such various end uses as ferroalloy production, blast furnace ironmaking, and manufacture of manganese chemicals.

Because the metric ton unit is 1% of a metric ton (i.e., 10 kilograms of contained manganese), the price of manganese in ore in 2000 and 1999 can be expressed as 23.9 and 22.6 cents per kilogram, respectively. These values indicate an increase of about 6% in U.S. c.i.f. price or somewhat less than the increase in free-on-board (f.o.b.) price in international markets.

The international benchmark price for metallurgical-grade ore ended a 3-year decline, increasing by about 7% in 2000, or by about the same percentage as for the decrease in 1999. Price negotiations between Japanese consumers, with Nippon Steel Corp. playing a leading role, and their major suppliers were not concluded until late May, or about 2 months after the April 1 beginning of the Japanese fiscal year. On an f.o.b. basis per metric ton unit for delivery during the annual contract year, the prices agreed to were $2.03 for ore from the Groote Eylandt Mine in Australia and $1.94 for ore from the Wessels Mine in South Africa. These prices were negotiated by South Africa's Samancor Ltd., a subsidiary of the United Kingdom's Billiton plc. Samancor had assumed control of both mines late in 1998.

Manganese Ferroalloys.—For high-carbon and medium-carbon ferromanganese, the pattern of price changes was

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similar, in a general way to that for the change in domestic raw steel production rate—an increase in the first part of the year to a plateau, followed by a decline thereafter. The silicomanganese price was nearly constant through June, after which it declined to a bottom in October that was followed by a modest recovery in November through December. These trends and the price information that follows pertain to quotations for U.S. imports because public information on current prices for domestic product was not available. English units were the basis for price quotes in the United States.

For ferromanganese, the price range for the high-carbon grade containing 78% manganese, per long ton of alloy f.o.b. Pittsburgh or Chicago warehouse, began the year unchanged at $450 to $470 and ended the year at $475 to $490, for a net overall increase of 5%. For the year, the average for the middle of the price range was $482.50, which was about 6% greater than that of 1999. The range for the plateau-like high that was reached as of mid-June was about $500 to $525. The price range for medium-carbon ferromanganese with a manganese content of 80% to 85% and a nominal carbon content of 1.5%, per pound of manganese f.o.b. warehouse, was an unchanged 35 to 38 cents at the beginning of the year and 42 to 45 cents at the end of the year, for a net overall increase of about 19%. The middle of the price range averaged 46 cents for the year, for an increase of 23% over that of 1999. The price range of medium-carbon ferromanganese rose sharply in April to a 3-month long plateau of 50 to 54 cents. During the first part of the year, trade journals spoke of a shortness in ferromanganese supply.

For imported silicomanganese with 2% carbon, the price range, per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, started the year at 24.5 to 26 cents, or slightly higher than that at the end of 1999, and ended the year at 21 to 22 cents, for a net decrease of 15%. Even so, an average for the year for the middle of the price range of about 23.8 cents was about 8% greater than that of 1999. At the bottom in October, the price range was 19.5 to 20.5 cents.

Manganese Metal.—Trade journals listed the same producer prices that they have been listing since about the beginning of 1996; for bulk shipments of domestic material, per pound f.o.b. shipping point, American Metal Market listed a range of $1.15 to $1.17, and Platt's Metals Week and Ryan's Notes listed $1.15. Platt's discontinued its listing as of its October 2 issue. For its listing of North American transaction price, Ryan's Notes indicated an overall decrease during the year that approached 9%. For this listing, the price range was more or less steady at 78 to 84 cents, January through November, but in December dropped to 72 to 77 cents. The year-average price of about 81 cents for this listing was about 30% below producer list price and about 5% less than that for 1999.

Foreign Trade

In comparison with those of 1999, trade volumes for most categories of manganese materials, in terms of manganese units contained, decreased for exports and increased for imports. (See tables 5 and 6.) Overall, the year-to-year comparisons were -14% for exports and +9% for imports. Also on the basis of content, the ratio of imports of ferroalloy plus metal divided by imports of ore plus dioxide tentatively increased, from 1.86:1 in 1999 to 2.0:1. In the absence of domestic mine production, U.S. net import reliance as a percent of apparent consumption was 100% for manganese, the same as it has been for years.

Within exports, the number of manganese units and the quantity of metal were the least since at least prior to 1983. Exports of ore reportedly were more than twice as great as in 1999. The data remained in question for 4,000 t or more of ore, particularly the large quantity reported as having been exported to the United Kingdom. Exports of manganese ferroalloys and metal all declined; those of total ferromanganese and silicomanganese were the least since 1990. Percentage declines from 1999 ranged from 31% for total ferromanganese to as much as 50% for silicomanganese. Most of the decline in ferromanganese exports was in the subcategory of carbon content greater than 2%. For this category, exports decreased by 49% and share of total ferromanganese exports declined to 43%. Exports of ferromanganese containing more than 2% carbon were 3,450 t and those containing less than 2% carbon were 4,500 t.

Reexports of ore, ferromanganese, silicomanganese, and metal were, in tons, 9,010; 10,600; 2,270; and 246; respectively. Except for metal, all or nearly all of the reexports went to Canada. Other main destinations of reexports of metal were the Republic of Korea, the Netherlands, and Mexico.

Among imports, overall average manganese contents were 78.8% for ferromanganese and tentatively 52.8% for ore. The average manganese content for ferromanganese was the greatest since the same level was attained in 1994. Average contents for ore were abnormally high (55% for ore with greater than 47% manganese). Averages were in question where ore was involved, however, as well as the ore data in general. Questions about obvious discrepancies in a significant portion of the data for Gabon were unresolved at the time this report was prepared. The ore data presented in table 5 indicate that overall imports decreased by 6% and that Gabon's share of receipts rose to 84%.

The import volume for total ferromanganese was virtually the same as in 1999. The most significant year-to-year change was for low-carbon ferromanganese, for which imports increased by 27%. The validity of the data for Brazil in this subcategory was in question, as it seemed likely that the more than 6,000 t reported as low-carbon ferromanganese was actually medium-carbon ferromanganese. If so, the quantity of medium-carbon ferromanganese imported would be a record high. Comparing leading supplying countries of medium-carbon ferromanganese with those in 1999, import volumes increased for China, Japan, and Norway, and decreased for France; for high-carbon ferromanganese, quantities increased for Australia and decreased for France. Declines in these subcategories were especially notable for France, from which imports of high-carbon ferromanganese fell by nearly one-half.

For silicomanganese, an import volume 26% greater than for 1999 was easily a new record. Record amounts were received from India and Kazakhstan, for which the amounts received were 5.6 and 2.4 times as great, respectively, as for 1999. For manganese metal overall, import volume was 5% greater than for 1999. For the unwrought subcategory, increases in shipments from China, Germany (especially), and the United Kingdom contributed to a 17% increase. Imports in the "Other" subcategory fell by two-thirds. Reported imports of spiegeleisen (pig iron containing about 20% manganese)

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declined to 270 t, all of which was from South Africa at high unit value.

Among imports of manganese chemicals, those of manganese dioxide increased for the second successive year by about one-fourth to set a new record for volume. Amounts received from Australia, Ireland, and South Africa set new records also, increasing by 14% to 19%. After Australia, South Africa continued to lead Ireland as the source of the largest amount. Unit values indicated that virtually all dioxide imports were synthetic material. Data for imports under the classification of "sulfates, other," suggested that imports of manganese sulfate may have decreased by 6%, as the volume of imports of material in that class decreased by 15% for China and increased only marginally for Mexico. Receipts from China were 13,100 t at a value of $4.8 million and those from Mexico 19,000 t at a value of $9.5 million.

Antidumping duties on EMD, manganese metal, and silicomanganese were the subject of investigations by Government trade agencies. For EMD, in May, the U.S. International Trade Commission determined in its full 5-year review that revocation of antidumping duty orders on EMD from Greece and Japan would be unlikely to cause material injury to a domestic industry in the reasonably foreseeable future (U.S. International Trade Commission, 2000a, b). Accordingly, the International Trade Administration (ITA) of the U.S. Department of Commerce revoked these antidumping duty orders effective January 1, 2000. In so doing, the ITA said it would complete pending administrative reviews of these orders and would conduct reviews of EMD imported prior to January 1, if appropriately requested (International Trade Administration, 2000e).

In reviews for EMD subsequently completed, for that from Greece for the period of review (POR) of April 1, 1998, through March 31, 1999, the ITA in November found a margin of 0.00% for Tosoh Hellas A.I.C.; no "all-others" rate was specified (International Trade Administration, 2000a). For that from Japan for the same POR, the ITA in September found a margin of 0.00% for Tosoh Corp. and also did not specify an "all-others" rate (International Trade Administration, 2000b).

For manganese metal from China, for the POR of February 1, 1998, through January 31, 1999, the ITA found a margin of 36.49% for China Metallurgical Import & Export Hunan Corp./Hunan Nonferrous Metals Import & Export Associated Corp. and an "all-others" margin of 143.32%, which also was assigned to China Hunan International Economic Development (Group) Corp. (International Trade Administration, 2000d).

For silicomanganese, the ITA found in its expedited 5-year ("sunset") review of the antidumping duty orders that applied to Brazil and China that revocation of the antidumping orders likely would lead to dumping. For Brazil, the corresponding weighted-average margins were 64.93% for Companhia Paulista de Ferro-Ligas and Sibra Electro-Siderurgia Brasileria S.A. and 17.6% for all others. For China, the margin was 150% for all manufacturers, producers, and exporters (International Trade Administration, 2000f). Also for silicomanganese from China, for the POR of December 1, 1997, through November 30, 1998, the ITA found margins of 126.22% for Guangxi Bayi Ferroalloy Works, 182.97% for Sichuan Emei Ferroalloy Import and Export Co., Ltd., and 150% for all others not specified (International Trade Administration, 2000g).

For silicomanganese from Ukraine, the ITA found in its full sunset review that termination of the suspended antidumping investigation likely would lead to dumping at a country-wide margin of 163% (International Trade Administration, 2000c).

The Generalized System of Preferences (GSP) Program was modified as of December 21 so as to grant duty-free status to certain products from sub-Saharan African countries. High-carbon ferromanganese was among the products to which this form of GSP treatment was extended (Clinton, 2000). Electrolytic manganese metal also had been a candidate for GSP treatment, but it was not included (Ryan's Notes, 2000).

World Review[1]

Leading producer countries among a relatively concentrated production of manganese ore were Australia, Brazil, China, Gabon, India, South Africa, and Ukraine. (See table 7.) Leading producer countries among a more widely distributed production of manganese ferroalloys were China, France, India, Japan, Norway, South Africa, and Ukraine. (See table 8.)

Australia.—Ore production was 15% less for Australia as a whole. Production in Western Australia by Consolidated Minerals Ltd. in the Woodie Woodie area of the Pilbara Manganese Province was nearly twice that for 1999. This did not compensate, however, for a drop in production of about one-fourth at Billiton plc's much larger operations at Groote Eylandt in the Northern Territory; the production level there was the lowest since 1992. Mining by Consolidated Minerals was adversely affected by heavy rains in the first part of the year, but the company still showed a profit for the fiscal year that ended June 30.

Expansion of EMD capabilities was underway on both sides of the continent. Delta EMD Australia Pty. Ltd. raised the annual capacity of its plant at Newcastle, New South Wales, from 23,000 to 25,000 t. In Western Australia, HiTec Energy NL further changed the direction of its program by raising its target capacity for EMD to 40,000 metric tons per year (t/yr) and reducing manganese sulfate to byproduct status, with no target capacity. Encouraging results for EMD produced for HiTec on a pilot plant basis under the technical direction of South Africa's Mintek research organization were to be followed up by operation of a demonstration plant to be set up in the first part of 2001 at Murdoch University in Perth.

Brazil.—Ore production by Cia. Vale do Rio Doce (CVRD) rebounded to increase overall by about 32%. For the Azul Mine in the Carajás region and the Urucum Mine in Mato Grosso do Sul State, output in tons and percentage change in parentheses from 2000 were 1,219,000 (+34%) and 308,000 (+22%), respectively.

Late in the year, CVRD made the decision to combine all its manganese interests into a single company, as opposed to other alternatives such as selling or partnering some or all of its mines and ferroalloy plants. Besides Brazilian operations, the

[1]In a number of instances, discussions of the more-significant developments during 2000 for specific countries were based on news items in trade journals, such as American Metal Market, Metal Bulletin, Platt's Metals Week, Ryan's Notes, and TEX Report. These items have not been acknowledged individually because the information they conveyed often was aggregated, possibly with that from other sources.

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new company would include the wholly owned ferroalloy plant at Dunkirk, France, whose name was changed as mentioned under France. Among its manganese ferroalloy plants in Brazil, the decision was made not to reopen that at Jeceaba in Minas Gerais State. The Corumbá plant in Mato Grosso do Sul State was reopened and was being upgraded. Output was being raised toward full capacity at Eletrosiderúrgica Brasileira S.A. in Bahia State and, in Minas Gerais State, at Barbacena, Ouro Preto, and Santa Ria. These efforts were projected to give a total production for the year of 240,000 t of manganese ferroalloys.

Shortly after midyear, the United Kingdom's Billiton acquired a 2.1% indirect shareholding in CVRD.

China.—Imports of manganese ore increased by 13% to 1.21 Mt. This ended a downward trend for imports during the preceding 3 years. A significant factor in the increase for 2000 was further growth in receipts from Ghana. Factors contributing to increased shipments from Ghana to China included suitability of Ghanian carbonate ore for production of silicomanganese, substitution for China's own low-grade ore, and use as an alternate to high-grade ore from other producers in the Western World.

In an effort to proceed with its program for rationalizing the domestic ferroalloy industry, the central government instructed local governments to end their financial support of a number of small- and medium-sized ferroalloy plants. How well this request was implemented was uncertain.

An agreement was worked out in the first part of the year with the Republic of Korea that liberalized restrictive measures imposed by the Republic of Korea in late 1998 against China's exporting of silicomanganese to the Republic of Korea (see Korea, Republic of).

France.—One of the high-carbon ferromanganese blast furnaces at the coastal Boulogne-sur-Mer plant of Société du Ferromanganèse de Paris-Outreau (SFPO), an Eramet subsidiary, was shut down during most of the second half of the year. This was done so that this furnace could be refurbished so as to be able to accept sintered ore produced in Gabon from manganese ore from Eramet's Moanda Mine. Also, a dry filtration system for improving environmental control was installed. The shutdown removed about 50,000 t of ferromanganese from the market and kept SFPO's output at about the 300,000 t level.

The name of CVRD's (Brazil) manganese ferroalloy plant, which also is on the coast nearby at Dunkirk, was changed at midyear to Rio Doce Manganese Europe (RDME) from Société Européenne d'Alliages pour la Sidérurgie (SEAS). This plant was producing high-carbon ferromanganese at a rate of about 140,000 t/yr, and also manganese sinter.

Gabon.—At yearend, Compagnie Minière de l'Ogooué S.A. (Comilog) inaugurated a sinter plant with a capacity of 600,000 t/yr along with associated facilities for beneficiating ore from the Moanda Mine. By this means, low-grade ore with a manganese content of 40% was to be upgraded to a sinter with a manganese content of 56% or more. Also, the sinter would effectively replace a portion of the mine's output of lump ore and reduce the quantity of crude ore needing to be extracted. Once the sinter plant's full capacity is reached, three-fourths of its output was to be shipped to SFPO in France for smelting and the balance sold externally.

Ghana.—Overall sales of ore produced at the Nsuta Mine of Ghana Manganese Co. rose by 40%. A significant portion of shipments were to China, particularly of carbonate ore; shipments to China were reported to have been in the range of 200,000 to 300,000 t.

Japan.—Overall imports of metallurgical-grade manganese ore that were only slightly less than those for 1999 gave the same rounded total of 1.02 Mt. The majority of imports were ore containing more than 39% manganese, imports of which decreased about 3% to 927,000 t, of which 94% was from the usual two sources, South Africa (546,000 t) and Australia (325,000 t). Imports of ore containing no more than 39% manganese increased 36%, to 90,900 t, of which virtually all was from South Africa (46,800 t) and India (44,000 t). Imports of ferruginous manganese ore again decreased, by about 38% to 128,000 t; Ghana (45%) displaced India (26%) as the largest supplier, followed by South Africa (19%) and Gabon (8%).

Overall production of manganese ferroalloys increased about 7%. Production of high-carbon ferromanganese and silicomanganese were up by about 13% and 3%, respectively, while that of low-carbon ferromanganese fell by about 11% to become the least since 1992.

Overall imports of manganese ferroalloys decreased about 7%, to 293,000 t. Those of high-carbon ferromanganese dropped again (53,500 t, -33%), those of medium- plus low-carbon ferromanganese rose again (16,200 t, +58%), and those of silicomanganese decreased about 2%, to 224,000 t. South Africa still led China as a source of ferromanganese overall for Japan; of these two countries, China supplied Japan with more high-carbon ferromanganese, while South Africa supplied about 10 times as much medium- plus low-carbon ferromanganese. Shipments of silicomanganese from China to Japan advanced about 16% to 180,000 t.

Exports of manganese ferroalloys more than doubled overall to 44,200 t. Exports of high-carbon ferromanganese increased almost 20 times, to 10,600 t, over 90% of which went to Taiwan. Exports of refined ferromanganese rose 78% to 33,600 t, of which 9,340 t went to the United States, 7,860 t to Taiwan, and 6,440 t to the Republic of Korea.

The year-to-year changes in trade patterns for manganese ferroalloys especially reflected production arrangements made within the past few years between Japanese and South African producers. In a further alignment, Japan's Nippon Denko Co. Ltd. and South Africa's Samancor Ltd. entered into an arrangement commencing April 2000 under which Nippon Denko was to produce high-carbon ferromanganese in place of that which Samancor had been shipping to Japanese customers, and Samancor was to increase its supply of manganese ore to Nippon Denko. The agreement, which included a technology exchange, would increase Nippon Denko's production of high-carbon ferromanganese at its Tokushima plant by about 50,000 t/yr above the 2000 level of about 130,000 t/yr. The agreement also would increase the quantity of Samancor manganese ore being taken by Nippon Denko from about 125,000 t/yr to 200,000 t/yr.

Production of manganese dioxide again rose, by 9%, to 63,400 t, the greatest since that for the record year of 1988. Exports of manganese dioxide declined, however, by 14% to 27,700 t.

Imports of unwrought manganese metal, including scrap, increased about 8%, to 43,300 t; China (77%), South Africa

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(20%), and the United States (3%) continued as the sources for practically all metal imports.

Kazakhstan.—The manganese deposits of central Kazakhstan and their commercial prospects were reviewed by Takenov and others (2000). Ores from the Ushkatyn III deposit were said to be especially suitable for production of high-carbon ferromanganese, and smelting trials of these ores were discussed.

Disagreement that extended back to 1997 over ownership of and marketing of products from a number of mines and smelters in Kazakhstan was finally resolved in February. Trans-World Group (TWG) of the United Kingdom and the Shodiyev Group reached a settlement under which TWG would be paid for its shares in the assets in dispute, and the Shodiyev Group would assume the managing and product marketing of these assets. The Shodiyev Group was headed by Kazakhstani nationals. The Aksu ferroalloy plant located near Pavlodar was among assets included in the settlement. Manganese ferroalloys are produced at the Aksu plant, which is a part of Kazkhrom, the national chrome corporation. The Tur manganese deposit, to the southwest and also in central Kazakhstan, was being developed as a manganese ore source for the Aksu plant.

Late in the year, a rebuilt furnace was started up for production of manganese ferroalloys at the Temirtau Chemicals and Metallurgical Plant near and to the northwest of Karaganda. The output of this plant, which could be as much as 50,000 t/yr of ferromanganese and silicomanganese combined, was to be shipped a short distance to the Ispat Karmet steel works (Interfax Mining & Metals Report, 2000c). Mining licenses for local ore sources for the Temirtau plant, however, became the subject of a dispute (Interfax Mining & Metals Report, 2000b).

Korea, Republic of.—In mid-March, the Government relaxed measures it took in September 1998 to restrict the importing of Chinese silicomanganese. Under the new measures, effective as of the April-June quarter, silicomanganese could be imported from China without an antidumping duty provided that the quantity per quarter did not exceed 20,000 t, and the price must not be below a floor price set by the Government of the Republic of Korea.

Mexico.—Overall output of ore products by Cía. Minera Autlán decreased by 9%; 2000 quantities in metric tons and, in parentheses, percentage changes from 1999 were manganese carbonates sold, 42,000 (-35%); oxide nodules, 355,000 (-6%); and manganese dioxide, manganous oxide, and other oxides, 21,000 (+31%). Production of nodules was affected when the natural gas-fired kiln being used to nodulize carbonate ore from the mine in Hidalgo State was shut down for December because of the high price of natural gas. Overall production of manganese ferroalloys increased; however, by 6,000 t to a new record total of 199,000 t. A 44% rise in production of high-carbon ferromanganese more than offset decreases of 7% and 5% for refined ferromanganese and silicomanganese, respectively.

In December, TETRA Technologies, Inc., The Woodlands, TX, sold the operations of Industrias Sulfamex, S.A. de C.V., a producer of manganese sulfate and manganous oxide, to Comilog U.S., a holding company subsidiary of Eramet. Capacities of Sulfamex' Tampico plant were 27,000 t/yr for the sulfate and 24,000 t/yr for the oxide (Chemetals Inc., 2000).

Norway.—During the last quarter of the year, Tinfos Jernverk A/S commissioned a new furnace at its Kvinesdal plant near the southern tip of Norway. Addition of this third furnace raised capacity of the plant for silicomanganese to approximately 180,000 t/yr, or by about 60,000 t/yr.

Russia.—The West Siberian Metallurgical Combine (ZSMK) at Novokuznetsk in southwestern Siberia commissioned mining and processing facilities from which as much as 100,000 t of low-grade concentrate (18% to 25% manganese content) would be produced from the Durnovskoye deposit. By this means, the need to import ores from Kazakhstan and Ukraine for ZSMK's steel production would be reduced (Interfax Mining & Metals Report, 2000e). The Durnovskoye deposit is near Leninsk-Kuznetsky, slightly north of Novokuznetsk.

Blast furnace production of ferromanganese decreased at the Kosogorsky metallurgical plant at Tula south of Moscow because only one furnace was being used to produce ferromanganese in at least the first part of the year (Interfax Mining & Metals Report, 2000d). Late in the year, legal troubles involving payments to Trans Commodities Inc. caused the Kosogorsky plant to be placed under court supervision (Interfax Mining & Metals Report, 2000a).

South Africa.—According to preliminary data, production of metallurgical-grade ore and total ore increased by about one-sixth to the highest levels since 1990. All but 0.6% of total production was metallurgical-grade ore, the rest being chemical-grade ore, production of which has been declining since 1996. Within the production of metallurgical-grade ore, the proportions accounted for by ore containing 30% to 40% manganese and by ore containing more than 48% manganese decreased slightly to about 29% and 57% of the total, respectively. Production of ore containing 45% to 48% manganese rose 26-fold to the highest level since 1990, and accounted for about 8% of production of metallurgical-grade ore.

Toward yearend, Samancor reconfigured manganese ferroalloy operations at its Metalloys plant at Meyerton near Johannesburg. Seven smaller furnaces that had been producing silicomanganese were shut down, possibly permanently. All but about 40,000 t/yr of the productive capacity of these furnaces potentially was to be made up once maintenance was completed on one of the three large furnaces at the plant. This furnace had been used to produce high-carbon ferromanganese but could be used to produce silicomanganese. Even with such a change, productive capacity for high-carbon ferromanganese was expected to be maintained using only the two remaining large furnaces owing to achievement of higher operational efficiencies.

In another development affecting Samancor's ferroalloys output, Samancor and Japan's Nippon Denko worked out a long-term agreement that would favor Samancor's shipping of ore rather than high-carbon ferromanganese to Japan (see Japan).

In June, Delta (E.M.D.) (Pty.) Ltd. announced that by the second half of 2001 it would expand the annual capacity of its EMD plant at Nelspruit, Mpumulanga Province, by 11,000 t, or by 50%. The expansion project included provision for infrastructure sufficient for an ultimate capacity of 50,000 t, and also installation of a kiln in Northern Cape Province for Delta EMD's own production of reduced ore feed. Feed from

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the kiln would supplement that currently being obtained from the adjacent plant of Manganese Metal Co. (Pty) Ltd. in Nelspruit (Industrial Minerals, 2000).

Spain.—In July, the permanganate business of Industrial Quimica del Nalón (IQN) was acquired by Carus Chemical Co., headquartered at Peru, IL, in the United States and one of the world's few producers of potassium permanganate. The acquisition was made a subsidiary of Carus named Carus Nalon S.L., which included the former IQN plant at Trubia on the north coast near Oviedo. In recent years, this plant had been the only site in the European Economic Community at which potassium permanganate was being produced (Carus Chemical Co., 2000).

Ukraine.—Output of manganese concentrates rose 38%, as production was up 30% to 1.82 Mt at the Ordzhonikidze complex in the western part of the Nikopol' Basin and 58% to 917,000 t at the Marganets complex in the eastern part of the basin (Interfax Mining & Metals Report, 2001b). Of a total production that was the greatest since 1997, about two-thirds was by the Ordzhonikidze complex and one-third by the Marganets complex.

A review of manganese mining and beneficiation in the Nikopol' basin gave the makeup of the Ordzhonikidze complex as eight quarries, three beneficiation plants, and one agglomeration plant. Practical annual capacities of these facilities were stated to be, in Mt per year, 7.1 for extraction of crude ore, 2.28 for production of manganese concentrates, and 0.4 for production of agglomerate. Makeup of the Marganets complex was given as five underground mines, two quarries, two beneficiation plants, and a facility for production of manganese sulfate in solid or solution form. Efforts were underway to deal with beneficiation wastes that consisted of more than 100 Mt with a manganese content of 12.2% at the Ordzhonikidze complex and 120 Mt with a manganese content of from 10% to 18% at the Marganets complex (Postolovskiy, Kravchenko, and Prokopenko, 2000).

Higher outputs at electric furnace plants contributed to an increased production of manganese ferroalloys. Production was up more than 50% at the Nikopol' plant and modestly at the Zaporozh'ye plant (Interfax Mining & Metals Report, 2001a, c). Limited quantities of ferroalloys having a reduced phosphorus content were produced at the Nikopol' plant. At the Kramatorsk Works north of Donetsk in eastern Ukraine, addition of fluxed sinter to the charge was found to improve blast furnace production of ferromanganese (Mishchenko and others, 2000). Also at this works, trials of blast furnace production of silicomanganese showed this unconventional way of making this ferroalloy to be inefficient.

Current Research and Technology

Among many items in the current literature that reported on various aspects of manganese and the topics addressed were the following:

Geology.—Model of sedimentation of banded iron formation and associated iron and manganese ores, with particular reference to South Africa (Klemm, 2000), and a review of manganese in seawater and marine deposits (Glasby, 2000).

Ore Leaching and Reduction.—Leaching of Indian manganese ore (about 32% Mn) with aqueous sulfur dioxide (Naik, Sukla, and Das, 2000), simultaneous leaching of zinc sulfide and manganese dioxide using iron-oxidizing bacteria (Kai and others, 2000), and reduction of manganese ore (Australian and South African samples) with carbon monoxide, in reference to manganese ferroalloy production (Berg and Olsen, 2000).

Electrochemistry of Manganese Oxides.—Summary of presentations made at a special meeting of the International Battery Materials Association on manganese oxides in batteries (Blomgren, 2000; MacArthur and Blomgren, 2001, p. 76-79), review of manganese dioxide electrochemistry (Donne, 2000), and comparison of EMD versus chemical and natural manganese dioxides as cathode material in alkaline batteries (Bowden, Sirotina, and Hackney, 2000).

Lithium-Manganese Oxides.—Intensive research continued to be directed on their use in rechargeable lithium-ion batteries; review of forms of oxides by Whittingham and Zavalij (2000), characterization of commercial powders (Huang and others, 2000), chromium substitution into layered oxides (Hwang, Park, and Choy, 2000), and development of a hydrothermal method for preparing a manganese oxide from a lithium manganese oxide (Tang and others, 2000).

Uses of Manganese Oxides.—Molecular sieves and their potential applications (Suib, 2000), manganese-molybdenum oxides as anodes for electrolysis of seawater (Fujimura and others, 2000), and thin film studies of manganese dioxide as a potential ultracapacitor material (Pang, Anderson, and Chapman, 2000).

Biology.—Review of availability of manganese to biological systems and its effect on them (Sigel and Sigel, 2000).

Environment and Toxicology.—Study of industrial hygiene at a domestic alkaline battery plant (Hanley and Lenhart, 2000) and at manganese ferroalloy plants in Italy (Apostoli, Lucchini, and Alessio, 2000) and Norway (Gunst and others, 2000).

Water Systems.—Control of manganese content in well water supply by using potassium permanganate (Fulton and Ferrand, 2000), and effect of biomineralized manganese on corrosion of steel (Olesen, Nielsen, and Lewandowski, 2000).

Outlook

The trend of domestic and global demand for manganese will continue to follow closely that of steel production. Although growth rates for some nonmetallurgical components of manganese demand, especially batteries, may be higher than for steel production, this situation will have only a minor effect on overall manganese demand.

From 1988 to 2000, U.S. apparent consumption of manganese has been within about plus or minus 14% of 680,000 t of contained manganese. This largely has been a consequence of a reasonably comparable degree of variation in domestic steel production. During this period, manganese apparent consumption (see table 1) has tended to increase at about the same rate as raw steel production. Manganese apparent consumption may not have tracked steel production precisely because of the influence of unmeasured changes in stocks of manganese materials, such as those of importers. The effect of this may have outweighed changes in demand by steelmakers and may explain why for some years calculated apparent consumption showed positive or negative deviations from that which could be estimated on the basis of steel

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production.

Data of the American Iron and Steel Institute indicated that overall domestic raw steel production increased in 2000 by about 4%, which makes it likely that domestic manganese consumption increased by about the same extent. The trend line for manganese apparent consumption suggests that consumption will reach 800,000 t within 5 years. This is contingent upon U.S. raw steel production maintaining the past trend of an annual growth rate close to 1.4%, and no significant change in manganese unit consumption by U.S. steelmakers. The outlook for steel production to increase at a rate similar to that for the past two decades was not favorable, at least in the immediate future, in view of a downturn in the domestic economy that was continuing into 2001. Also, the October 2000 midterm forecast for 2000 through 2005 of the International Iron and Steel Institute (IISI) suggested a slow recovery, as the compound annual growth rate projected for steel consumption in the North American Free Trade Agreement countries was only 0.9% (Ian Christmas, Secretary General, International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth, accessed June 1, 2001, at URL http://www.worldsteel.org/trends_indicators/demand.html). For the automotive industry, demand for steel was seen as remaining important but in decline overall, whereas cast iron seemed increasingly likely to be replaced by aluminum (Wrigley, 2000). The majority of U.S. demand for manganese units will be met by imports.

Globally, growth trends for manganese demand similarly are linked strongly with steel production, which rose to a record level in 2000. In its October 2000 midterm steel consumption forecast for 2000 through 2005, the IISI projected an annual growth rate of 2% for the world overall. Higher growth rates were projected for Asian countries other than Japan; for China, the rate projected was 3.8%. One of the major companies in the world's manganese industry was not optimistic about growth in the midterm, foreseeing a growth of only 1.9% in the amount of steel produced worldwide during 2000 through 2005 (Bacardats, 2000). This company also foresaw that growth in global manganese demand would be held down by decreases in manganese unit consumption, particularly in countries such as China. Consumption was expected to trend downward for high-carbon ferromanganese and upward for silicomanganese and refined manganese ferroalloys. Buying patterns of U.S. steel mills were reported to be in line with this outlook (Ryan's Notes, 2001). Like the steel industry, the manganese industry continued to be challenged by overcapacity for mining and smelting.

References Cited

Advanced Battery Technology, 2000, USA—Military battery market grows: Advanced Battery Technology, v. 36, no. 12, December, p. 8-9.

Agency for Toxic Substances and Disease Registry, 2000, Availability of final toxicological profiles: Federal Register, v. 65, no. 222, November 16, p. 69309-69310.

Apostoli, Pietro, Lucchini, Roberto, and Alessio, Lorenzo, 2000, Are current biomarkers suitable for the assessment of manganese exposure in individual workers?: American Journal of Industrial Medicine, v. 37, no. 3, March, p. 283-290.

Bacardats, Jacques, 2000, Eramet ferro-alloys—Manganese and nickel markets in perspective: Metal Bulletin International Ferro-Alloys Conference, 16th, Paris, November 19-22, 2000, slide presentation, unpaginated.

Berg, K.L., and Olsen, S.E., 2000, Kinetics of manganese ore reduction by carbon monoxide: Metallurgical and Materials Transactions B, v. 31B, no. 3, June, p. 477-490.

Blomgren, G.E., 2000, Meeting report—IBA-2000 Manganese Oxide Symposium: Advanced Battery Technology, v. 36, no. 7, July, p. 20-25.

Bowden, W., Sirotina, R., and Hackney, S., 2000, Manganese dioxide for alkaline zinc batteries—Why electrolytic MnO_2?: ITE Letters on Batteries, New Technologies & Medicine (with News), v. 1, no. 6, p. 903-914.

Carus Chemical Co., 2000, Carus finalizes acquisition of Spanish permanganate business: Peru, IL, Carus Chemical Co. press release, July 31, 1 p.

Chemetals Inc., 2000, Comilog U.S. buys manganese sulfate business: Baltimore, MD, press release, December 18, 1 p.

Clinton, W.J., 2000, Proclamation 7388, 2000—To modify duty-free treatment under the Generalized System of Preferences for sub-Saharan African countries and for other purposes: Federal Register, v. 65, no. 246, December 21, p. 80723-80732.

Day, Kathleen, 2001, Sacagawea comes up tails: Washington Post, January 26, p. A1, A16.

Donne, S.W., 2000, Alkaline manganese dioxide electrochemistry: ITE Letters on Batteries, New Technologies & Medicine (with News), v. 1, no. 6, p. 915-925.

Drug Enforcement Administration, 2000, January 17, 1998 shipment of 10,000 kilograms of potassium permanganate, December 16, 1997 shipment of 20,000 kilograms of potassium permanganate and November 17, 1997 shipment of 20,000 kilograms of potassium permanganate—Suspension of shipments: Federal Register, v. 65, no. 164, August 23, p. 51333-51338.

Employment and Training Administration, 2000, Notice of determinations regarding eligibility to apply for worker adjustment assistance and NAFTA transitional adjustment assistance: Federal Register, v. 65, no. 246, December 21, p. 80456-80459.

———2001, Eramet Marietta Incorporated North Plant, Marietta, OH—Notice of revised determination on reopening: Federal Register, v. 66, no. 8, January 11, p. 2452-2453.

Ferlay, Serge, and Weill, Patric, 2000, Used batteries—A global solution: ITE Letters on Batteries, New Technologies & Medicine (with News), v. 1, no. 4, p. 530-534.

Fujimura, K., Matsui,, T., Habazaki, H., Kawashima, A., Kumagai, N., and Hashimoto, K., 2000, The durability of manganese-molybdenum oxide anodes for oxygen evolution in seawater electrolysis: Electrochimica Acta, v. 45, no. 14, p. 2297-2303.

Fulton, G.P., and Ferrand, S.T., 2000, Manganese removal: Public Works, v. 131, no. 11, October, p. 66-74.

Glasby, G.P., 2000, Manganese—Predominant role of nodules and crusts, *in* Schulz, H.D., and Matthias, Zabel, eds., Marine Geochemistry: Berlin, Springer-Verlag, p. 335-372.

Gunst, Stefan, Weinbruch, Stephan, Wentzel, Michael, Ortner, H.M., Skogstad, Asbjørn, Hetland, Siri, and Thomassen, Yngvar, 2000, Chemical composition of individual aerosol particles in workplace air during production of manganese alloys: Journal of Environmental Monitoring, v. 2, no. 1, p. 65-71.

Haflich, Frank, 2000, Bunny replacing Oregon Steel: American Metal Market, v. 108, no. 64, April 4, p. 5.

Hanley, K.W., and Lenhart, S.W., 2000, Manganese dioxide exposures and respirator performance at an alkaline battery plant: Applied Occupational and Environmental Hygiene, v. 15, no. 7, p. 542-549.

Harben, Peter, Raleigh, Charles, and Harris, Jeanette, 1998, Manganese uses & markets: London, Industrial Minerals Information Ltd., 110 p.

Huang, H., Chen, C.H., Perego, R.C., Kelder, E.M., Chen, L., Schoonman, J., Weydanz, W.J., and Nielsen, D.W., 2000, Electrochemical characterization of commercial lithium manganese oxide powders: Solid State Ionics, v. 127, nos. 1-2, p. 31-42.

Hwang, Seong-Ju, Park, Hyo-Suk, and Choy, Jin-Ho, 2000, Effects of chromium substitution on the chemical bonding nature and electrochemical performance of layered lithium manganese oxide: Journal of Physical Chemistry B, v. 104, no. 32, p. 7612-7618.

Industrial Minerals, 2000, Delta boosts EMD capacity as batteries power market growth: Industrial Minerals, no. 394, July, p. 8.

Interfax Mining & Metals Report, 2000a, Court places Kosoya Gora works under supervision: Interfax Mining & Metals Report, v. 9, issue 50, December 8-14, p. 21.

———2000b, Kazakh firm demands reinstatement of manganese ore licenses: Interfax Mining & Metals Report, v. 9, issue 49, December 1-7, p. 24.

———2000c, Kazakhstan gains new ferroalloy producer: Interfax Mining & Metals Report, v. 9, issue 44, October 27-November 3, p. 34.

———2000d, Kosogorsky metals plant raises output by 3.5% in Q1: Interfax Mining & Metals Report, v. 9, issue 15, April 7-13, p. 15.

———2000e, ZSMK steel works starts to produce manganese concentrate:

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Interfax Mining & Metals Report, v. 9, issue 29, July 14-20, p. 17.
———2001a, Nikopol ferroalloy works targets 750,000 tonnes of alloys in 2001: Interfax Mining & Metals Report, v. 10, issue 2, January 5-11, p. 20.
———2001b, Ukraine ups manganese concentrate production 38%: Interfax Mining & Metals Report, v. 10, issue 6, February 2-8, p. 31.
———2001c, ZZF may halt production due to fall in gas supplies: Interfax Mining & Metals Report, v. 10, issue 4, January 19-25, p. 30-31.
International Trade Administration, 2000a, Electrolytic manganese dioxide from Greece—Final results of antidumping duty administrative review: Federal Register, v. 65, no. 221, November 15, p. 68978-68979.
———2000b, Electrolytic manganese dioxide from Japan—Final results of antidumping duty administrative review: Federal Register, v. 65, no. 180, September 15, p. 55939-55940.
———2000c, Final results of full sunset review—Silicomanganese from Ukraine: Federal Register, v. 65, no. 188, September 27, p. 58045-58046.
———2000d, Manganese metal from the People's Republic of China—Final results of antidumping duty administrative review: Federal Register, v. 65, no. 91, May 10, p. 30067-30068.
———2000e, Revocation of antidumping duty orders—Electrolytic manganese dioxide from Greece and Japan: Federal Register, v. 65, no. 105, May 31, p. 34661.
———2000f, Silicomanganese from the People's Republic of China and Brazil—Final results of antidumping duty expedited sunset reviews: Federal Register, v. 65, no. 107, June 2, p. 35324-35325.
———2000g, Silicomanganese from the People's Republic of China—Notice of final results of antidumping duty administrative review: Federal Register, v. 65, no. 97, May 18, p. 31514-31515.
Iron & Steelmaker, 2000, Study sheds light on steel consumption: Iron & Steelmaker, v. 27, no. 11, p. 17.
Kai, Takami, Suenaga, Yo-ich, Migita, Atsuko, and Takahashi, Takeshige, 2000, Kinetic model for simultaneous leaching of zinc sulfide and manganese dioxide in the presence of iron-oxidizing bacteria: Chemical Engineering Science, v. 55, no. 17, p. 3429-3436.
Klemm, D.D., 2000, The formation of Palæoproterozoic banded iron formations and their associated Fe and Mn deposits, with reference to the Griqualand West deposits, South Africa: Journal of African Earth Sciences, v. 30, no. 1, p. 1-24.
MacArthur, D.M., and Blomgren, G.E., 2001, The Powers review—Year 2000 battery industry developments: Chemac International Corp., 98 p.
Mining Magazine, 1990, Manganese: Mining Magazine, v. 162, no. 1, January, p. 36-40.
Mishchenko, I.M., Varava, V.I., Bondarenko, N.M., Malkin, V.I., Krizhevskii, A.Z., and Osadchii, V.P., 2000, Making blast-furnace ferromanganese with the use of fluxed manganese-bearing sinter: Metallurgist, v. 44, nos. 9-10, p. 522-526.
Naik, P.K., Sukla, L.B., and Das, S.C., 2000, Aqueous SO_2 leaching studies on Nishikhal manganese ore through factorial experiment: Hydrometallurgy, v. 54, nos. 2-3, January, p. 217-228.
Olesen, B.H., Nielsen, P.H., and Lewandowski, Z., 2000, Effect of biomineralized manganese on the corrosion behavior of C1008 mild steel: Corrosion, v. 56, no. 1, January, p. 80-89.
Pang, Suh-Cem, Anderson, M.A., and Chapman, T.W., 2000, Novel electrode materials for thin-film ultracapacitors—Comparison of electrochemical properties of sol-gel-derived and electrodeposited manganese dioxide: Journal of the Electrochemical Society, v. 147, no. 2, February, p. 444-450.
Platt's Metals Week, 2000, Eramet shuts US manganese metal production: Platt's Metals Week, v. 71, no. 30, July 24, p. 6-7.
Postolovskiy, V.V., Kravchenko, P.A., and Prokopenko, V.I., 2000, [Extraction and treatment of manganese ores in the Nikopol' basin]: Gorny Zhurnal, June, p. 169-171.
Ryan's Notes, 2000, Little movement in bulk ferroalloy tags: Ryan's Notes, v. 6, no. 52, December 25, p. 2.
———2001, More woes for US bulk ferroalloy suppliers: Ryan's Notes, v. 7, no. 1, January 1, p. 2-3.
Sciences International, Inc., 2000, Toxicological profile for manganese: Atlanta, GA, Agency for Toxic Substances and Disease Registry, 465 p., 3 appendices.
Sigel, Astrid, and Sigel, Helmut, eds., 2000, Manganese and its role in biological processes, v. 37 *of* Metal ions in biological systems: New York, Marcel Dekker, Inc., 761 p.
Skillings Mining Review, 2000, Zemex sells metal powders division to Höganäs of Sweden: Skillings Mining Review, v. 89, no. 19, May 6, p. 10.
Suib, S.L., 2000, Sorption, catalysis, separation: Chemical Innovation, v. 30, no. 3, March, p. 27-33.
Takenov, T.D., Baisanov, S.O., Tolymbekov, M.Zh., Zhakibekov, T.B., and Akhmetov, A.B., 2000, [Manganese ore base and prospects for production of ferromanganese from local raw materials in Kazakhstan]: Stal', 2000, no. 6, June, p. 40-42.
Tang, W., Kanoh, H., Ooi, K., and Wang, Y., 2000, Preparation of a new type of manganese oxide by selective lithium extraction from monoclinic Li_2MnO_3 for lithium rechargeable batteries: Journal of Materials Science Letters, v. 19, no. 15, p. 1361-1363.
TETRA Technologies, Inc., 2001, TETRA Technologies, Inc., annual report 2000: The Woodlands, TX, TETRA Technologies, Inc., 22 p. plus appendices.
U.S. International Trade Commission, 2000a, Electrolytic manganese dioxide from Greece and Japan: Federal Register, v. 65, no. 96, May 17, p. 31348.
———2000b, Electrolytic manganese dioxide from Greece and Japan: U.S. International Trade Commission Publication 3296, May, variously paginated.
Weiss, S.A., 1977, Manganese—The other uses: London, Metal Bulletin Books, Ltd., 360 p.
Whittingham, M.S., and Zavalij, P.Y., 2000, Manganese dioxide as cathodes for lithium rechargeable cells—The stability challenge: Solid State Ionics, v. 131, nos. 1-2, p. 109-115.
Wickramanayake, G.B., Gavaskar, A.R., and Chen, A.S.C., eds., 2000a, Field application of in situ permanganate oxidation, *in* Chemical oxidation and reactive barriers—Remediation of chlorinated and recalcitrant compounds: International Conference on Remediation of Chlorinated and Recalcitrant Compounds, 2d, Monterey, CA, May 22-15, 2000, p. 91-152.
———2000b, Treatability studies and modeling for in situ oxidation with permanganate, *in* Chemical oxidation and reactive barriers—Remediation of chlorinated and recalcitrant compounds: International Conference on Remediation of Chlorinated and Recalcitrant Compounds, 2d, Monterey, CA, May 22-15, 2000, p. 1-90.
Wrigley, Al, 2000, Metals still ride high in drive for lighter autos: American Metal Market, v. 108, no. 38, February 28, p. 6.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Manganese. Ch. in Metal Prices in the United States Through 1998, 1999.
Manganese. Ch. in Mineral Commodity Summaries, annual.
Manganese. Ch. in Minerals Yearbook, annual.
Manganese. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Manganese. International Strategic Minerals Inventory Summary Report, Circular 930-A, 1984.
Manganese. Mineral Industry Surveys, monthly.

Other

Advanced Battery Technology.
American Metal Market.
Annual reports of various companies.
Engineering and Mining Journal.
Industrial Minerals (London).
ITE Letters on Batteries, New Technologies & Medicine (with News).
Manganese. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Metal Bulletin (London).
Mining Journal (London).
Mining Magazine (London).
Platt's Metals Week.
Proceedings of ferroalloy conferences (INFACON, etc.).
Roskill Information Services Ltd. (London; last reported on manganese in 2000).
Ryan's Notes.
Skillings Mining Review.
TEX Report (Tokyo; daily issues and annual ferroalloy manual).

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TABLE 1
SALIENT MANGANESE STATISTICS 1/

(Thousand metric tons, gross weight)

	1996	1997	1998	1999	2000
United States:					
Manganese ore (35% or more Mn):					
Exports	32	84	8	4	10
Imports for consumption	478	355	332	460	430
Consumption 2/	478	510	499	479	486
Stocks, December 31, consumers 2/	319	241	163	172	226
Ferromanganese:					
Exports	10	12	14	12	8
Imports for consumption	374	304	339	312	312
Consumption 3/	326	337	290	281	300
Stocks, December 31, consumers and producers	27	21	26	40	31
Consumption, apparent, manganese 4/	776	643	776	719	774
Ore price, dollars per metric ton unit, c.i.f. U.S. ports	3	2	2	2	2
World, production of manganese ore	24,300	21,900	20,100 r/	17,900 r/	20,200 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Exclusive of iron and steel plants.

3/ Data for 1998 and later not directly comparable to that for prior years.

4/ Thousand metric tons, manganese content. Based on estimates of average content for all significant components except imports, for which content is reported.

TABLE 2
U.S. GOVERNMENT DISPOSAL AUTHORITIES AND INVENTORIES FOR MANGANESE MATERIALS AS OF YEAREND 2000 1/

(Metric tons, gross weight)

		Physical inventory				
		Uncommitted			Sold,	
Material	Disposal authority	Stockpile grade	Nonstockpile grade	Total	pending shipment	Grand total
Natural battery ore	106,000	89,500	16,800	106,000	874	107,000
Synthetic manganese dioxide	2,730	2,730	--	2,730	--	2,730
Chemical ore	137,000	137,000	--	137,000	4,010	141,000
Metallurgical ore	878,000	547,000	331,000	878,000	103,000	982,000
High-carbon ferromanganese	582,000	772,000	--	772,000	78,900	851,000
Electrolytic metal	5,640	5,640	--	5,640	146	5,790

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Defense National Stockpile Center.

TABLE 3
DOMESTIC PRODUCERS OF MANGANESE PRODUCTS IN 2000

		Products 1/				
Company	Plant location	FeMn	SiMn	Mn	MnO_2	Type of process
Chemetals Inc. 2/	Baltimore, MD				X	Chemical.
Do.	New Johnsonville, TN				X	Electrolytic.
Eramet Marietta Inc.	Marietta, OH	X	X	X		Electric furnace and electrolytic.
Kerr-McGee Chemical LLC	Hamilton, MS			X		Electrolytic.
Do.	Henderson, NV				X	Do.
Ralston Purina Co., Eveready Battery Co. 3/	Marietta, OH				X	Do.

1/ FeMn, ferromanganese; SiMn, silicomanganese; Mn, manganese metal; MnO_2, synthetic manganese dioxide.

2/ Name changed to Erachem Comilog Inc. as of January 1, 2001.

3/ Spun off into Energizer Holdings, Inc., as of April 1, 2000.

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TABLE 4
U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 200(

(Metric tons, gross weight)

End use	Ferromanganese			Silico-manganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	125,000	101,000	225,000	74,600	1,340
High-strength, low-alloy	22,700	4,120	26,800	4,930	(2/)
Stainless and heat-resisting	13,700	(2/)	13,700	6,350	1,530
Full alloy	15,500	6,610	22,100	19,600	(2/)
Unspecified 3/	299	332	631	275	195
Total	177,000	112,000	289,000	106,000	3,060
Cast irons	8,660	503	9,160	1,340	5
Superalloys	W	W	W	--	W
Alloys (excluding alloy steels and superalloys)	1,570	629	2,200	(4/)	18,300 5/
Miscellaneous and unspecified	--	W	W	(4/)	W
Total consumption	187,000	113,000	300,000	107,000 6/	21,400
Total manganese content 7/	146,000	90,200	236,000	70,700	21,400
Stocks, December 31, consumers and producers	11,300	20,200	31,500	10,700	4,750

W Withheld to avoid disclosing company proprietary data; included with "Alloys (excluding alloy steels and superalloys)." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
3/ Includes electrical and tool steel, and items indicated by (2/).
4/ Withheld to avoid disclosing company proprietary data.
5/ Approximately 85% of this combined total was for consumption in aluminum alloys.
6/ Internal evaluation indicates that silicomanganese consumption is considerably understated.
7/ Estimated based on typical percent manganese content.

TABLE 5
U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY 1/

Country	1999		2000	
	Gross weight (metric tons)	F.a.s. value (thousands)	Gross weight (metric tons)	F.a.s. value (thousands)
Ore and concentrates with 20% or more manganese:				
Canada	1,250	$332	4,160	$1,020
Germany	--	--	589	278
Italy	--	--	350	172
Norway	--	--	333	136
Singapore	2,440	180	24	12
United Kingdom	136	11	3,800	304
Other	351 2/	128 2/	776	277
Total	4,170	651	10,000	2,200
Ferromanganese, all grades:				
Canada	10,700	5,920	7,610	4,910
Mexico	94	107	231	266
Venezuela	749	431	--	--
Other	54	54	111	106
Total	11,600	6,510	7,950	5,290
Silicomanganese:				
Canada	3,360	1,850	1,460	942
Mexico	250	220	373	221
Other	95	109	34	35
Total	3,700	2,180	1,870	1,200
Metal, including alloys and waste and scrap:				
Brazil	125	268	--	--
Canada	1,490	3,580	762	1,680
Japan	659	1,470	773	1,620
Mexico	111	299	248	491
Netherlands	190	411	73	136
United Kingdom	711	1,060	17	43
Other	254 2/	850 2/	349	1,050
Total	3,540	7,940	2,220	5,020

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY 1/

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Revised; unspecified group of countries differs from that in the 1999 Annual Report.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Manganese content (metric tons)	1999 Customs value (thousands)	2000 Gross weight (metric tons)	2000 Manganese content (metric tons)	2000 Customs value (thousands)
Ore and concentrates with 20% or more manganese:						
All grades:						
Australia	44,900	23,500	$4,380	34,800	18,100	$3,280
Brazil	2	1	2	7,030	3,250	373
Gabon	280,000	142,000	25,600	363,000	196,000	27,200
Ghana	26,100	10,200	505	17,400	6,510	209
Mexico	23,600	9,130	1,980	8,080	3,250	1,050
South Africa	85,300	39,100	4,690	--	--	--
Other	100	55 2/	54	132	97	29
Total	460,000	224,000	37,200	430,000	227,000	32,100
More than 20%, but less than 47% manganese:						
Brazil	--	--	--	7,030	3,250	373
Gabon	--	--	--	38,000	16,100	2,170
Ghana	26,100	10,200	505	17,400	6,510	209
Mexico	22,500	8,600	1,910	8,080	3,250	1,050
South Africa	27,300	9,970	1,410	--	--	--
Other	18	6	7	--	--	--
Total	75,900	28,800	3,840	70,500	29,100	3,800
47% or more manganese:						
Australia	44,900	23,500	4,380	34,800	18,100	3,280
Brazil	2	1	2	--	--	--
Gabon	280,000	142,000	25,600	325,000	180,000	25,000
South Africa	58,000	29,200	3,280	--	--	--
Other	1,170	572 2/	117	132	97	29
Total	384,000	195,000	33,400	360,000	198,000	28,300
Ferromanganese:						
All grades:						
Australia	11,700	8,920	4,600	30,400	22,800	11,500
Brazil	6,580	5,000	2,430	14,800	11,600	6,370
China	7,280	5,530	3,540	7,630	6,240	5,330
France	96,300	74,500	45,300	45,300	35,800	19,500
Italy	3,800	3,260	4,620	5,520	4,700	5,390
Japan	6,920	5,900	6,120	10,900	9,060	8,080
Korea, Republic of	10,800	8,760	6,210	8,550	6,840	5,060
Mexico	27,600	22,200	16,600	23,600	19,000	15,800
Norway	20	9	19	10,500	8,560	6,170
South Africa	140,000	110,000	59,400	151,000	119,000	66,600
Other	1,340	1,060	533	3,400	2,690	1,510
Total	312,000	245,000	149,000	312,000	246,000	151,000
1% or less carbon:						
Brazil	--	--	--	6,410	5,140	2,920
China	1,280	1,110	1,270	1,410	1,250	1,490
Italy	3,800	3,260	4,620	5,520	4,700	5,390
Japan	6,500	5,540	5,610	4,660	3,920	3,980
Mexico	2,220	1,770	2,010	1,570	1,260	1,350
South Africa	3,740	3,290	3,970	2,490	2,330	3,880
Other	69	64	70	230	211	229
Total	17,600	15,000	17,600	22,300	18,800	19,200

See footnotes at end of table.

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TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Manganese content (metric tons)	1999 Customs value (thousands)	2000 Gross weight (metric tons)	2000 Manganese content (metric tons)	2000 Customs value (thousands)
Ferromanganese--Continued:						
More than 1% to 2% or less carbon:						
China	--	--	--	6,230	4,990	$3,840
France	9,540	7,700	$7,970	60	48	37
Japan	424	361	511	6,250	5,140	4,100
Korea, Republic of	10,800	8,760	6,210	8,550	6,840	5,060
Mexico	25,400	20,400	14,600	20,700	16,700	13,800
Norway	20	9	19	10,500	8,520	6,140
South Africa	25,100	20,400	14,100	25,300	20,500	15,800
Other	--	--	--	188	150	130
Total	71,300	57,600	43,400	77,800	62,900	48,900
More than 2%, but not more than 4% carbon:						
Brazil	--	--	--	1	(3/)	2
South Africa	--	--	--	57	46	46
Total	--	--	--	58	46	48
More than 4% carbon:						
Australia	11,700	8,920	4,600	30,400	22,800	11,500
Brazil	6,580	5,000	2,430	8,310	6,410	3,370
China	6,000	4,420	2,260	--	--	--
France	86,700	66,800	37,300	45,200	35,700	19,500
South Africa	111,000	86,500	41,200	124,000	96,000	46,900
Other	1,270	994	463	4,540	3,550	1,880
Total	224,000	173,000	88,300	212,000	164,000	83,200
Silicomanganese:						
Australia	67,500	45,000	26,600	52,400	35,500	24,300
France	6,740	4,500	2,930	1,350	918	636
Georgia	13,400	9,900	5,470	6,250	4,390	2,940
India	10,900	7,020	4,340	60,500	39,300	26,200
Kazakhstan	27,700	18,800	10,900	66,400	45,200	28,400
Mexico	58,800	38,600	24,900	45,400	29,700	21,000
Norway	--	--	--	4,400	2,680	2,780
Romania	--	--	--	9,630	6,360	4,170
South Africa	89,300	60,000	35,800	97,400	65,400	43,600
Ukraine	8,190	6,030	2,850	--	--	--
Venezuela	16,900	11,100	6,530	24,100	16,100	10,500
Other	1,190	753	694	10,300	6,710	4,890
Total	301,000	202,000	121,000	378,000	252,000	169,000
Metal:						
Unwrought:						
China	2,770	XX	3,860	3,320	XX	4,410
Germany	255	XX	433	1,760	XX	2,360
South Africa	8,910	XX	14,100	9,160	XX	13,900
Ukraine	429	XX	622	20	XX	23
United Kingdom	497	XX	976	627	XX	1,120
Other	40	XX	69	193	XX	288
Total	12,900	XX	20,100	15,100	XX	22,100
Other:						
China	1,700	XX	847	92	XX	162
France	29	XX	308	92	XX	841
Netherlands	33	XX	67	80	XX	148
Ukraine	119	XX	129	189	XX	204
Other	162 4/	XX	1,200 4/	211	XX	911
Total	2,040	XX	2,550	663	XX	2,270
Waste and scrap:						
Canada	130	XX	183	433	XX	357
China	22	XX	61	--	XX	--
Norway	--	XX	--	20	XX	16

See footnotes at end of table.

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TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Manganese content (metric tons)	1999 Customs value (thousands)	2000 Gross weight (metric tons)	2000 Manganese content (metric tons)	2000 Customs value (thousands)
Manganese dioxide:						
Australia	21,400	XX	$30,200	25,400	XX	$36,500
Belgium	591	XX	913	769	XX	1,260
China	24	XX	31	1,060	XX	1,320
Greece	16	XX	22	1,580	XX	2,060
Ireland	8,380	XX	11,700	9,510	XX	13,100
South Africa	10,400	XX	14,700	12,200	XX	17,200
Other	154 4/	XX	628 4/	633	XX	1,300
Total	40,900	XX	58,200	51,200	XX	72,700
Potassium permanganate:						
Czech Republic	750	XX	1,410	824	XX	1,590
India	420	XX	749	481	XX	873
Spain	491	XX	704	156	XX	352
Other	59 4/	XX	111 4/	60	XX	136
Total	1,720	XX	2,980	1,520	XX	2,950

XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes U.S. Geological Survey's conversion of part of reported data (from apparent MnO_2 content to Mn content).
3/ Less than 1/2 unit.
4/ Revised; unspecified group of countries differs from that in the 1999 Annual Report.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

TABLE 7
MANGANESE ORE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	Range percent Mn e/ 4/	Gross weight 1996	1997	1998	1999	2000 e/	Metal content 1996	1997	1998	1999	2000 e/
Australia 5/	37-53	2,109	2,136	1,500	1,892	1,614 6/	1,023	1,024	729	926	787 6/
Brazil 7/	30-50	2,506	2,124	2,149	1,674 r/	2,000	977	977 r/	988 r/	770 r/	920
China e/ 8/	20-30	7,600	6,000	5,300	3,190 r/	4,000	1,520	1,200	1,060	630 r/	800
Gabon 9/	45-53	1,983	1,904	2,092	1,908 r/	1,743 6/	915	879	966	881 r/	804 6/
Ghana	30-50	448	437	537	639 r/ 10/	896 10/	152	149	172 e/	204 r/	287
India 11/	10-54	1,797	1,596	1,557	1,500 e/	1,550	680 e/	606 e/	592 e/	570 e/	590
Kazakhstan (crude ore) e/	20-30	430	400	634 6/	980 6/	1,136 6/	106	98	155	240	280
Mexico 12/	27-50	485	534	510	459	418	173	193	187	169	156
South Africa 9/	30-48+	3,240	3,121	3,044	3,122	3,635 6/	1,381 r/	1,324 r/	1,298 r/	1,343 r/	1,578 6/
Ukraine	30-35	3,070	3,040	2,226	1,985 r/	2,741 6/	1,040 e/	1,030 e/	755 e/	675 e/	930
Other e/ 13/	XX	632 r/	608	551 r/	551 r/	467	201 r/	181 r/	159 r/	162 r/	147
Total	XX	24,300	21,900	20,100 r/	17,900 r/	20,200	8,170 r/	7,660 r/	7,060 r/	6,570 r/	7,280

e/ Estimated. r/ Revised. XX Not applicable.
1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 26, 2001. Data pertain to concentrates or comparable shipping product, except that in a few instances the best data available appear to be for crude ore, possibly after some upgrading.
3/ In addition to the countries listed, Burkina Faso, Cuba, Panama, and Sudan may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels.
4/ May be average content of each year's production rather than for content of typical products.
5/ Metallurgical ore.
6/ Reported figure.
7/ Production of beneficiated ore as reported in Sumário Mineral (Brasilia).
8/ Includes manganiferous ore.
9/ Calculated metal content includes allowance for assumed moisture content.
10/ Sales.
11/ Much of India's production grades below 35% Mn; content averaged 38.3% Mn for fiscal years 1998-99 through 1999-2000.
12/ Mostly oxide nodules; may include smaller quantities of direct-shipping carbonate and oxide ores for metallurgical and battery operations.
13/ Category represents the combined totals of Bosnia and Herzegovina, Bulgaria, Burma, Chile, Colombia, Egypt, Georgia, Greece, Hungary, Indonesia, Iran, Italy (from wastes), Japan (low-grade ore), Malaysia, Morocco, Namibia, Romania, Russia (crude ore), Thailand, and Turkey.

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TABLE 8
FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons, gross weight)

Country 3/	1996					1997				
	Ferromanganese			Silico-manganese	Grand total	Ferromanganese			Silico-manganese	Grand total
	Blast furnace	Electric furnace	Total			Blast furnace	Electric furnace	Total		
Argentina	--	7	7	25	32	--	8	8	26	35
Australia e/	--	110	110	95	205	--	95	95	95	190
Belgium e/ 4/	--	25	25	--	25	--	25	25	--	25
Brazil	--	215	215	232	447	--	153	153	175	328
Chile	--	8	8	2	10	--	6	6	3	9
China e/	450	700	1,150	840	1,990	500	680	1,180	770	1,950
Egypt e/	--	35	35	--	35	--	26 r/	26 r/	--	26 r/
France 5/	337	100	437	61 e/	498 e/	326	100	426	66 e/	492 e/
Georgia e/	--	8	8	7	15	--	4	4	17	21
Germany e/ 4/	--	10 r/	10 r/	--	10 r/	--	-- r/	-- r/	--	-- r/
India e/	--	190	190	170	360	--	166	166	198	364
Indonesia e/	--	14	14	7	21	--	15	15	7	22
Italy	--	25	25	100	125	--	40 r/	40 r/	100 e/	140 r/ e/
Japan	--	343	343	76	419	--	377	377	78	455
Kazakhstan e/	--	--	--	50	50	--	--	--	55	55
Korea, North e/ 4/	--	6	6	--	6	--	6	6	--	6
Korea, Republic of	--	126	126	83	210	--	159	159	77 r/	236 r/
Mexico 6/	--	69	69	93	162	--	68	68	105	173
Norway e/	--	215 7/	215 7/	210	425	--	235	235	230	465
Poland	60	--	60	25	85	48 e/	--	48 e/	20	68 e/
Romania	--	20	20	79	99	--	12	12	63	74
Russia 8/	67	--	67	--	67	47	--	47	--	47
Slovakia e/	--	25	25	12	37	--	20	20	45 r/ 7/	65 r/
South Africa	--	548 r/	548 r/	254 r/ e/	802 r/ e/	--	499 r/	499 r/	286 e/	785 r/ e/
Spain e/	--	16 r/	16 r/	102 r/	118 r/	--	23 r/	23 r/	122 r/	145 r/
Taiwan	--	14	14	--	14	--	12	12	--	12
Ukraine e/	100	170	270	600	870	125	160	285	560	845
Venezuela	--	--	--	53 r/	53 r/	--	--	--	64 r/	64 r/
Total	1,010	3,000 r/	4,010 r/	3,180 r/	7,190 r/	1,050	2,890 r/	3,930 r/	3,160 r/	7,100 r/

	1998					1999				
	Ferromanganese			Silico-manganese	Grand total	Ferromanganese			Silico-manganese	Grand total
	Blast furnace	Electric furnace	Total			Blast furnace	Electric furnace	Total		
Argentina	--	5	5	25	30	--	2 r/ e/	2 r/ e/	10 r/ e/	12 r/ e/
Australia e/	--	110	110	105	215	--	98 r/	98 r/	116 r/	214 r/
Belgium e/ 4/	--	20	20	--	20	--	--	--	--	--
Brazil	--	122	122	124	246	--	85 r/	85 r/	148 r/	234 r/
Chile	--	4	4	4	8	--	4 e/	4 e/	4 e/	8 e/
China e/	550	500	1,050	639	1,690	550 r/	550	1,100 r/	822 r/	1,920 r/
Egypt e/	--	18 r/	18 r/	--	18 r/	--	30 r/	30 r/	--	30 r/
France 5/	321 e/	100 e/	421 e/	65 e/	486 e/	302	138 r/ e/	440 r/ e/	55 r/ e/	495 r/ e/
Georgia e/	--	10	10	35	45	--	7 r/	7 r/	25 r/	32 r/
Germany e/ 4/	--	-- r/	-- r/	--	-- r/	--	-- r/	-- r/	--	-- r/
India e/	--	165	165	193	358	--	160	160	190	350
Indonesia e/	--	13	13	7	20	--	12 r/	12 r/	7	19 r/
Italy	--	49 r/	49 r/	70 r/	119 r/	--	19 r/	19 r/	67 r/	86 r/
Japan	--	334	334	71	405	--	315	315	66	381
Kazakhstan e/	--	--	--	57	57	--	--	--	75	75
Korea, North e/ 4/	--	6	6	--	6	--	6	6	--	6
Korea, Republic of	--	158	158	107	265	--	140 r/	140 r/	116 r/	256 r/
Mexico 6/	--	87	87	105	192	--	79	79	114	193
Norway e/	--	235	235	230	465	--	235	235	230	465
Poland	50	--	50	15 r/	65 r/	60 e/	--	60 e/	25	85 e/
Romania	--	4	4	84	88	--	(9/)	(9/)	1	1
Russia 8/	65	--	65	--	65	90 e/	--	90 e/	--	90 e/
Slovakia e/	--	20	20	47 r/ 7/	67 r/	--	20	20	37 r/	57 r/
South Africa	--	542 r/	542 r/	265 e/	807 r/ e/	--	527 r/	527 r/	267 r/	794 r/
Spain e/	--	18 r/	18 r/	108 r/	126 r/	--	10 r/	10 r/	95 r/	105 r/
Taiwan	--	13	13	--	13	--	--	--	--	--
Ukraine e/	112 7/	150	262	486 7/	748	58	200 r/ 7/	257 r/ 7/	499 7/	756 r/
Venezuela	--	8	8	49 r/	57 r/	--	11 e/	11 e/	48 r/	59 r/ e/
Total	1,100	2,690	3,790	2,890 r/	6,680 r/	1,060 r/	2,650	3,710 r/	3,020 r/	6,720 r/

See footnotes at end of table.

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TABLE 8--Continued
FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons, gross weight)

Country 3/	2000 e/				
	Ferromanganese			Silico-manga-nese	Grand total
	Blast furnace	Electric furnace	Total		
Argentina	--	--	--	--	--
Australia e/	--	115	115	135	250
Belgium e/ 4/	--	--	--	--	--
Brazil	--	110	110	150	260
Chile	--	4	4	4	8
China e/	500	520	1,020	900	1,920
Egypt e/	--	30	30	--	30
France 5/	300	140	440	60	500
Georgia e/	--	7	7	25	32
Germany e/ 4/	--	--	--	--	--
India e/	--	160	160	185	345
Indonesia e/	--	12	12	7	19
Italy	--	40	40	90	130
Japan	--	338 7/	338 7/	68 7/	406 7/
Kazakhstan e/	--	5	5	100	105
Korea, North e/ 4/	--	6	6	--	6
Korea, Republic of	--	140	140	110	250
Mexico 6/	--	91	91	108	199
Norway e/	--	235	235	230	465
Poland	60	--	60	25	85
Romania	--	1 7/	1 7/	21 7/	22 7/
Russia 8/	71	--	71	--	71
Slovakia e/	--	20	20	35	55
South Africa	--	530	530	270	800
Spain e/	--	10	10	100	110
Taiwan	--	--	--	--	--
Ukraine e/	85	253 7/	338	684 7/	1,022
Venezuela	--	--	--	50	50
Total	1,020	2,770	3,780	3,360	7,140

e/ Estimated. r/ Revised. -- Zero.

1/ Table includes data available through July 25, 2001.

2/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Iran is believed to have produced ferromanganese and silicomanganese, but production figures are not reported; general information is inadequate for the formulation of reliable estimates of output levels. Production of manganese ferroalloys, ferrosilicon, and silicon metal began in 1996 for Saudi Arabia, but data for actual production were not available. Data for U.S. production of manganese ferroalloys are not included to avoid disclosing company proprietary data.

4/ Ferromanganese includes, if any, silicomanganese.

5/ Silicomanganese includes, if any, silicospiegeleisen.

6/ Salable products from Autlán.

7/ Reported figure.

8/ Russia is believed to have produced some silicomanganese during 1996-99, but data for actual production were not available.

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MERCURY

By Robert G. Reese, Jr.

Domestic survey data and tables were prepared by Adam A. Wario, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

As has been the case for more than a decade, recycled mercury-containing devices accounted for essentially all domestic mercury production in 2000. No domestic mine produced mercury as its primary product. Several companies were engaged in mercury refining, the three largest being in the Eastern and Central United States. Chlorine-caustic soda production was again the largest end use for mercury.

Legislation and Government Programs

The U.S. Geological Survey (USGS) in 2000 was directly involved in a broad range of national and international studies related to mercury and its distribution and mobility in the environment. Activities included data collection, long-term assessments, ecosystem analysis, predictive modeling, and process research on the occurrence, distribution, recycling, and fate of mercury. Much of this work was conducted in partnership with other Federal and State agencies.

During 2000, the USGS published a map showing the distribution of mercury in the Warrior coalfield in Alabama (Goldhaber and others, 2000). Using data from over 900 chemical analyses contained in the USGS National Coal Resources Data System, the authors found that the Warrior coal field contained higher levels of mercury and a suite of other trace elements when compared with the average for all U.S. coal. The map used three-dimensional plots of Warrior coalbeds to show mercury abundance and concentration.

On November 2, the U.S. Environmental Protection Agency (EPA) announced a ban on discharges of various bio-accumulative chemicals, including mercury, in the Great Lakes Basin. Under the ban, the discharges into mixing zones would be phased out over a 10-year period, while new discharges were banned immediately. Mixing zones are areas where toxic chemical discharges are permitted to mix with receiving waters and be diluted. EPA also announced plans to develop regulations covering discharges of bioaccumulative chemicals, including mercury, through mixing zones in 2001 (U.S. Environmental Protection Agency, 2000a).

On December 14, EPA announced plans to begin regulating mercury emissions from coal-fired powerplants. The Agency plans to announce proposed regulations during 2003 and to issue final regulations in 2004 (U.S. Environmental Protection Agency, 2000b).

Production

Since 1990, no domestic mine has produced mercury as its primary product. Owing in part to regulations controlling mercury discharges to the environment, however, some domestic mines and plants recovered small amounts of mercury. These mines and plants were located in areas that historically produced large amounts of mercury, such as California, Nevada, and Utah.

Nearly all the mercury produced in the United States was derived from secondary sources, including spent batteries, mercury vapor and fluorescent lamps, switches, dental amalgams, measuring devices, control instruments, and laboratory and electrolytic refining wastes. The secondary processors typically use high-temperature retorting to recover mercury from compounds and distillation to purify the contaminated liquid mercury metal. Among the largest producers of refined mercury from scrap material were the following companies: Bethlehem Apparatus Co. Inc., Hellertown, PA; D.F. Goldsmith Chemical and Metal Corp., Evanston, IL; and Mercury Waste Solutions, Inc., Minneapolis, MN.

Consumption

The USGS estimated that the electrolytic production of chlorine and caustic soda and electrical applications were the largest uses for mercury in the United States, accounting for approximately 50% and 25% of domestic consumption, respectively. Only in dental applications, where it is the most

Mercury in the 20th Century

In 1901, the United States, with an output of more than 1,000 metric tons, was the world's largest mercury producer. Mercury imports were insignificant, and with shipments of nearly 390 tons, the United States was a net mercury exporter. Among the largest uses for mercury during the first half of the century were the production of explosives, pharmaceuticals, various fungicides and bactericides, dental amalgams, batteries, switches, and measuring and control instruments such as barometers. For much of the century, the United States remained among the largest mercury-producing countries. Because of mercury's toxic nature, however, various rules and regulations were enacted, especially in the 1970s, to eliminate or curtail human exposure to mercury.

By the end of the century, there were no longer any producing mercury mines in the United States, and domestic production was limited to the metal recovered from scrap materials. In 2000, the United States was a net mercury exporter, with most of the material shipped to India and the Netherlands. It is estimated that the largest domestic use for mercury is in the production of chlorine and caustic soda.

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cost-effective and longest lasting dental cavity-filler, has the quantity of mercury consumed remained steady.

World Review

During the past 10 years, annual world mercury production has averaged about 2,500 t, nearly all of which was produced at mines where mercury is the primary product. Most countries do not report their mercury production, and world production values have a high degree of uncertainty. In 2000, about 10 countries produced mercury, with Kyrgyzstan and Spain the dominant producing nations. In some countries, a few base-metal operations recover small quantities of mercury to meet environmental standards and avoid environmental releases of the metal.

In June, a contract transporter for the Yanacocha gold mine in Peru spilled about 151 kilograms of mercury near the town of Choropampa. Minera Yanacocha S.R.L. undertook a comprehensive health and environmental remediation program, agreed to provide a number of public works for nearby communities, and paid a fine of approximately $500,000 as compensation for the spill (Newmont Mining Corp., 2001, p. 24).

Outlook

Ever stricter environmental regulations and the development of new technology are expected to be the primary factors affecting mercury supply and demand in the near future. Environmental standards and technological advances likely will work in tandem to reduce the demand for mercury in commercial products. Even as the per-unit mercury product content declines, regulations on the disposal of mercury will prompt more recycling of mercury-bearing material to recover the contained mercury. Consequently, secondary mercury is expected to remain the principal component of domestic supply. Other potential sources of domestic supply could include mercury in the National Defense Stockpile and the mercury recovered from the dismantling of mercury cells in some chloralkali operations.

References Cited

Goldhaber, Martin, Bigelow, R.C., Hatch, J.R., and Pashin, J.C., 2000, Distribution of a suite of elements including arsenic and mercury in Alabama coal: U.S. Geological Survey Miscellaneous Field Studies Map MF-2333, 1 sheet, various scales.

Newmont Mining Corp., 2001, Form 10-K: Security and Exchange Commission, 58 p.

U.S. Environmental Protection Agency, 2000a, EPA to reduce toxic chemical discharged into the Great Lakes: Washington, DC, U.S. Environmental Protection Agency press release, November 2, 2 p.

———2000b, EPA decides mercury emissions from power plants must be reduced: Washington, DC, U.S. Environmental Protection Agency press release, December 14, 2 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Mercury. Ch. in Mineral Commodity Summaries, annual.

Mercury. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

The Materials Flow of Mercury in the United States, U.S. Bureau of Mines Information Circular 9412, 1994.

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TABLE 1
SALIENT MERCURY STATISTICS 1/

(Metric tons, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Secondary production, industrial	446	389	NA	NA	NA
Imports for consumption	340	164	128	62	103
Exports	45	134	63	181	178
Industry stocks, yearend 2/	446	203	NA	NA	NA
Industrial consumption	372	346	NA	NA	NA
Price, average per flask: 3/					
D.F. Goldsmith	$261.65	NA	NA	NA	NA
Free market	NA	$159.52	$139.84	$140.00	$155.00
World mine production	2,560	2,950 r/	1,950 r/	1,630 r/	1,640 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Stocks at consumers and dealers only. Mine stocks withheld to avoid disclosing company proprietary data.

3/ Source: Platt's Metals Week.

TABLE 2
U.S. IMPORTS AND EXPORTS OF MERCURY, BY COUNTRY 1/

(Gross weight, unless otherwise specified)

	1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Imports:				
Australia	--	--	25	$58
Canada	2	$6	4	16
Chile	16	28	--	--
Germany	4	114	25	797
Netherlands	(2/)	10	--	--
Peru	7	14	11	21
Russia	--	--	17	64
Taiwan	--	--	4	101
United Kingdom	32	129	17	70
Total	62	301	103	1,130
Exports:				
Brazil	1	10	--	--
Canada	4	32	7	48
China	1	4	--	--
France	5	70	2	27
Germany	1	13	2	17
India	85	228	65	175
Israel	1	12	1	10
Italy	3	44	--	--
Japan	1	8	14	181
Korea, Republic of	4	33	14	68
Malaysia	1	10	1	7
Mexico	4	47	7	56
Netherlands	9	251	51	1,210
Peru	--	--	4	30
Singapore	19	93	1	11
Spain	17	126	--	--
Thailand	2	22	3	26
United Kingdom	1	10	4	58
Other	22 r/	103 r/	2	109
Total	181	1,120	178	2,040

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 3
MERCURY: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria	368	447	224	240 r/	240
China e/	510	830	230	200	200
Finland	88	63 r/	54 r/	40 r/	45
Kyrgyzstan	584	610 e/	620	620	550
Mexico e/	15	15	15	15	25
Russia e/	50	50	50	50	50
Slovakia	--	--	20 e/	--	--
Slovenia	5	5 e/	5 e/	--	--
Spain	862	863	675	433 r/	500
Tajikistan e/	45	40	35	35	40
Ukraine e/	30	25	20	NA	NA
United States 3/	W	W	NA	NA	NA
Total	2,560	2,950 r/	1,950 r/	1,630 r/	1,640

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 2, 2001.

3/ Mercury was produced only as a byproduct of gold mining.

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MICA

By James B. Hedrick

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

The mica group currently represents 37 phyllosilicate minerals that have a layered or platy texture (Rieder and others, 1998). (Phyllo is derived from the Greek word *phyllon*, meaning leaf.) The commercially important micas are muscovite and phlogopite.

The value of mica is in its unique physical properties. The crystalline structure of mica forms layers that can be split or delaminated into thin sheets. These sheets are flexible, elastic, platy, transparent to opaque, resilient, reflective, refractive, dielectric, chemically inert, insulating, lightweight, and hydrophilic. Mica also is stable when exposed to electricity, light, moisture, and extreme temperatures. Based on its greater abundance and superior electrical properties, muscovite is the principal mica used by industry. Phlogopite remains stable at higher temperatures and is used in applications where a combination of high-heat stability and electrical properties is required. Muscovite and phlogopite are used in sheet and ground forms.

In 2000, about 101,000 metric tons (t) of scrap and flake mica was produced in the United States, 6% more than that of 1999 (tables 1, 3). Ground mica sales were 112,000 t, a slight increase in tonnage of 1% compared with 1999, and were valued at $37.5 million. Essentially all sheet mica used in the United States was imported, and India was the major supplier. Consumption of muscovite block mica decreased to 5.9 t valued at $132,000. Consumption of mica splittings decreased to 583 t in 2000 from 786 t in 1999. Worked and unworked sheet mica exports decreased to 1,280 t in 2000 from 1,290 t in 1999, and the value decreased by 7% to $17.4 million. U.S. imports of worked and unworked sheet mica increased to 5,710 t in 2000 from 4,550 t in 1999, and the value decreased by 2% to $14.1 million.

Legislation and Government Programs

The National Defense Authorization Act for Fiscal Year 2000 (Public Law 106-65), which was enacted on October 5, 1999, did not change the previous authorization for the disposal of stocks of mica in excess of the National Defense Stockpile (NDS) goals. Stocks of mica classified as excess to goal at the end of fiscal year 1999 (September 30, 1999) were all subject to either no disposal limits or were below the disposal limits previously specified. Excess NDS mica stocks were 283,322 kilograms (kg) (624,619 pounds) of muscovite block (stained and better), 702 kg (1,548 pounds) of muscovite film (1st and 2nd qualities), 5,232,975 kg (11,536,734 pounds) of muscovite splittings, 234,345 kg (516,643 pounds) of phlogopite splittings, and 53,498 kg (117,942 pounds) of phlogopite block. The law authorized the transfer of no more than $150 million from the NDS Transaction Fund to the operation and maintenance accounts (no more than $50 million each) of the Army, Navy, and Air Force (section 304). The law also obligated no more than $78.7 million of the NDS Transaction Fund for the operation of the NDS program, including disposal of hazardous materials that are environmentally sensitive.

The Floyd D. Spence National Defense Authorization Act for

Mica in the 20th Century

In 1900, mica production was at an all-time high owing to increased use of small-sized mica, which was previously considered a waste product. Much of this small-sized material was recovered from scrap heaps at existing mine sites to complement the shop scrap used to meet the flourishing demand from the electric industry. At the turn of the 20th century, sheet mica was used primarily in stove windows, chimneys and lampshades on open-flame gas and oil lights, and furnace peephole covers. Most of these uses of large-sized mica sheet were in decline with the advent of the domestic electric industry. The demand for small-sized material for use as insulators in electric motors, coil insulators in magnetos in early gasoline engines, insulators in spark plugs, and in nonelectric phonographs, which had a stylus set in a mica diaphragm, was increasing. Other sheet mica uses were as windows in horse-drawn buggies and in boiler gauges. Wet-ground mica was used in turn-of-the-century wallpaper, and coarsely ground material was used as an artificial snow during the winter holidays. The primary use of dry-ground mica was in the rolled roofing and asphalt industry where it was used to prevent sticking. Dry-ground mica was also used as an additive in axle grease and special lubricants and in quack medicines and elixirs. In the early days of electric power generation, sheet mica was the only material available with electrical and mechanical properties suitable to operate at the temperatures necessary for the efficient functioning of the electrical equipment. In 1900, U.S. production of sheet mica was 207 metric tons valued at $92,758.

In 2000, U.S. production of sheet mica was negligible. Imports of sheet mica were 5,710 tons valued at $14.1 million. Sheet mica was used primarily in electric motors, with lesser amounts used as spacers and washers in electronics and as insulation in toasters, electric hair dryers, and hair curling irons. Sheet mica was also used in stove windows, lamp shades, and in turn-of-the-century reproduction wallpaper. Ground mica production in 2000 was 112,000 tons valued at $37.5 million. Major uses of dry-ground mica were in house paints and in joint compound for drywall. Wet-ground mica was used in pearlescent paints for automobile coatings, to add sparkle and shimmer in cosmetics, in plastic reinforcement fillers, in nylon and polyester resins, and in polypropylene composites.

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Fiscal Year 2001 (Public Law 106-398), which was enacted on October 30, 2000, continued the funding of $150 million ($50 million each) of the operation and maintenance accounts of the Army, Navy, and Air Force by the NDS Transaction Fund. The law obligated no more than $71 million of the NDS Transaction Fund for the operation of the NDS program, including disposal of hazardous materials that are environmentally sensitive, a decrease of $7.7 million from that of 1999. The revised Annual Material Plan for fiscal year 2000 authorized the disposal of 1,025,119 kg (2,260,000 pounds) of mica (all types) from the NDS classified as excess to goal. Stocks of mica classified as excess to goal at the end of fiscal year 2000 (September 30, 2000) were all subject to either no disposal limits or were below the disposal limits previously specified. Excess NDS mica stocks were 51,836 kg (114,279 pounds) of muscovite block (stained and better), 674 kg (1,485 pounds) of muscovite film (1st and 2nd qualities), 4,168,229 kg (9,189,371 pounds) of muscovite splittings, 232,554 kg (512,693 pounds) of phlogopite splittings, and 15,902 kg (35,058 pounds) of phlogopite block (table 2).

Production

Domestic mine production data for mica are developed by the U.S. Geological Survey from four separate voluntary surveys. Of the 14 operations to which the "Crude Scrap and Flake Mica" production form (including sericite production) was sent, 9 operations responded. Of the 16 operations to which the "Ground Mica" form was sent, 6 operations responded and 1 had not started grinding (excludes low-grade ground sericite production). Of the five surveyed operations to which the "Mica Block and Film" consumption form was sent, four operations responded. Of the nine surveyed operations to which the "Mica Splittings" consumption form was sent, seven operations responded. Consumption for the nonrespondents was estimated by using prior-year production data. Individual company production and consumption data are withheld to avoid disclosing company proprietary data.

AZCO Mining Inc. reported that it had completed a production run at the end of 1999 at its mica mine at Black Canyon, AZ. The mine produced an initial run of 7,000 t of high-grade green-colored muscovite. The stockpile of ore from the Black Canyon Mica Mine was expected to be sufficient to supply AZCO's Glendale processing plant at Glendale, AZ, with feed for a full year. The mine, which is on Federal land, was expected to produce muscovite from a swarm of pegmatite dikes that occur over a distance of 1,524 meters (m) with widths varying from 3 to 18 m (AZCO Mining Inc., 2000b).

AZCO Mining Inc. announced that its subsidiary, Azco Mica Inc. of Glendale, AZ, began production of a wet-ground cosmetic grade mica. The mica is a pearl-white muscovite mica with high luster and translucence that is available in two particle ranges, 1 to 50 microns and 5 to 70 microns. The company also has the capability to produce high aspect ratio mica that is used in plastics and pearlescent paints (AZCO Mining Inc, 2000a).

Zemex Industrial Minerals Inc. (ZIM), a subsidiary of Zemex Corp., announced that its phlogopite operations in Canada had a very strong year. This fact, however, was offset by the fact that ZIM had to put its Spruce Pine, NC, mica operation, which it purchased from Aspect Minerals, Inc. in 1998, on a care and maintenance basis because of decreased availability of byproduct feed material. Feed for the plant had relied more heavily on mined byproduct; however, inconsistencies in the grade and quality of the ores in conjunction with increased processing costs resulted in the decision to idle the facility (Zemex Corp., 2001).

Oglebay Norton Specialty Minerals, Inc. (ONSM), a subsidiary of Oglebay Norton Co., produced dry- and wet-ground mica from its mining and processing operations near Kings Mountain, NC, and Velarde, NM. ONSM, which acquired Franklin Industries' mica business in 1999, increased its earnings because demand was strong for mica products in 2000 (Oglebay Norton Co., 2001).

Scrap and Flake Mica.—In 2000, 8 domestic companies with 11 mines in 6 States produced scrap and flake mica (excluding low-grade sericite). The United States was one of the world's primary producers with 101,000 t (tables 1, 3). North Carolina remained the major producing State, with 46% of domestic production, and the remainder was produced in Georgia, New Mexico, South Carolina, South Dakota, and Virginia. Mica was recovered from mica schist, high-quality sericite schist, weathered pegmatites, a gemstone pegmatite, and as a coproduct of feldspar and kaolin.

The scrap and flake mica producers, in alphabetical order, were AZCO Mining Inc., Black Canyon, AZ (contract basis); Engelhard Corp., Hartwell, GA; The Feldspar Corp., a Zemex Industrial Minerals company, (2 mines) Spruce Pine, NC; K-T Feldspar Corp., Spruce Pine, NC; Oglebay Norton Specialty Minerals, Inc., Kings Mountain, NC, and Velarde, NM; The Mineral Mining Co. Inc., Kershaw, SC; Pacer Corp., Custer, SD; Tinton Enterprises, Spearfish, SD; Unimin Corp., Spruce Pine, NC; and Zemex Mica Corp., a Zemex Industrial Minerals company, Micaville, NC.

Ground Mica.—In 2000, 11 companies operated 16 grinding plants in 6 States; 11 plants produced dry-ground mica, and 5, wet-ground mica. The four largest ground mica companies, including one company with four plants, accounted for 64% of the total of 112,000 t (table 4).

Dry-ground mica producers, in alphabetical order, were Asheville Mica Co., Asheville, NC; Georgia Industrial Minerals, Inc., Deep Step, GA; AZCO Mining Inc., Glendale, AZ; The Mineral Mining Co. Inc., Kershaw, SC; Oglebay Norton Specialty Minerals Inc. (2 plants), Kings Mountain, NC, and Velarde, NM; Pacer Corp., Custer, SD; Piedmont Minerals Corp., Hillsborough, NC; USG Corp., Spruce Pine, NC; and Zemex Mica Corp., a Zemex Industrial Minerals company, Spruce Pine, NC.

Wet-ground mica producers, in alphabetical order, were AZCO Mining Inc., Glendale, AZ; Engelhard Corp., Hartwell, GA; Oglebay Norton Specialty Minerals Inc., Kings Mountain, NC; and Zemex Mica Corp., a Zemex Industrial Minerals company, Bakersville, NC.

Sheet Mica.—Small quantities of muscovite sheet and scrap mica were produced as a byproduct by Morefield Gem Mine, Inc., in Amelia Co., VA. The pegmatite was mined primarily for gemstones and mineral samples using underground methods. The mine also produced biotite and zinnwaldite mica.

Consumption

Statistics on domestic mica consumption are developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments.

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Sheet Mica.—Sheet mica is used principally in the electronic and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties and its mechanical properties, which allow it to be cut, punched, stamped, and machined to close tolerances.

The largest use of block mica is as an electrical insulator in electronic equipment. High-quality block mica is processed to line the gauge glasses of high-pressure steam boilers because of its transparency, flexibility, and resistance to heat and chemical attack. Other uses include diaphragms for oxygen-breathing equipment, marker dials for navigation compasses, optical filters, retardation plates in helium-neon lasers, pyrometers, thermal regulators, and stove and kerosene heater windows. Specialized applications for sheet mica are found in aerospace components in ground- and air-launched missile systems, optical instrumentation, laser devices, medical electronics for radiation treatment, and radar systems.

Only high-quality muscovite film mica is used as a dielectric in capacitors. The highest quality film is used to manufacture capacitors for calibration standards. The next grade down is used in transmitting capacitors. Receiving capacitors use a slightly lower grade of high-quality muscovite.

In 2000, consumption of muscovite block (ruby and nonruby) totaled 5,940 kg, a 10% decrease compared with that of 1999 (table 5). Stained and lower than stained quality remained in greatest demand, accounting for 96.1% of ruby mica block. Consumption of nonruby mica block was split—88% for stained quality and 12% for good quality. The use of block mica was lower as demand in electronic and nonelectronic applications decreased.

In 2000, five companies continued to consume muscovite block and film in five plants in four States—two in North Carolina and one each in New Jersey, Ohio, and Virginia. In 2000, mica splittings represented the largest part of the sheet mica industry in the United States. Consumption of muscovite and phlogopite splittings decreased by 26% to 583 t (table 6). Muscovite splittings from India accounted for essentially all of the domestic consumption. The remainder of consumption was primarily phlogopite splittings imported from Madagascar. Muscovite and phlogopite splittings were fabricated into various built-up mica products by nine companies operating nine plants in seven States.

Built-Up Mica.—Produced by mechanical or hand setting of overlapping splittings and alternate layers of binders and splittings, built-up mica is primarily used as an electrical insulation material. Major products are bonding materials, flexible plate, heater plate, mica paper, molding plate, segment plate, and tape (table 7).

Segment plate acts as insulation between the copper commutator segments of direct-current universal motors and generators. Phlogopite built-up mica is preferred because it will wear at the same rate as the copper segments. Although muscovite has a greater resistance to wear, it causes uneven ridges that may interfere with the operation of a motor or generator. Consumption of segment plate was 10 t in 2000 (table 7).

Molding plate is sheet from which v-rings are cut and stamped for use in insulating the copper segments from the steel shaft ends at the end of a commutator. Molding plate is also fabricated into tubes and rings for insulation in transformers, armatures, and motor starters. Consumption of molding plate increased by 11% to 194 t in 2000 from 175 t in 1999 (table 7).

Flexible plate (cold) is used in electric motor and generator armatures, field coil insulation, and magnet and commutator core insulation. Mica consumption in flexible plate decreased to 61 t in 2000 from 125 t in 1999 (table 7).

Heater plate is used where high-temperature insulation is required. Consumption of mica in heater plate increased by 1% in 2000 compared with that of 1999.

Some types of built-up mica have the bonded splittings reinforced with cloth, glass, linen, muslin, plastic, silk, or special paper. These products are very flexible and are produced in wide, continuous sheets that are either shipped rolled or cut into ribbons, tapes, or trimmed to specified dimensions. Built-up mica products are also corrugated or reinforced by multiple layering.

The total amount of built-up mica that was consumed or shipped was 358 t, a decrease of 32.7% compared with that of 1999 (table 7). In 2000, molding plate and flexible plate (cold) were the major end products and accounted for 54% and 17% of the total, respectively.

Mica Paper (Reconstituted Mica).—Primary uses for mica paper are the same as those for built-up mica. Three companies consumed scrap mica to produce mica paper. The principal source of the scrap was India. In 1999, manufacturing companies, in alphabetical order, were Corona Films Inc., West Townsend, MA; General Electric Co., Coshocton, OH; and U.S. Samica Corp., Rutland, VT.

Ground Mica.—The largest domestic use of dry-ground mica was in joint compound for filling and finishing seams and blemishes in gypsum wallboard (drywall) (table 4). The mica acts as a filler and extender, provides a smooth consistency, improves the workability of the compound, and provides resistance to cracking. In 2000, joint compound accounted for 44% of dry-ground mica consumption.

In the paint industry, ground mica is used as a pigment extender that also facilitates suspension, reduces chalking, prevents shrinking and shearing of the paint film, increases resistance of the paint film to water penetration and weathering, and brightens the tone of colored pigments. Mica also promotes paint adhesion in aqueous and oleoresinous formulations. Consumption of dry-ground mica in paint, its second largest use, accounted for 30% of the 2000 total.

Ground mica is used in the well-drilling industry as an additive to drilling muds. The coarsely ground mica flakes help prevent the loss of circulation by sealing porous sections of the drill hole.

The rubber industry uses ground mica as an inert filler and a mold release compound in the manufacture of molded rubber products, such as tires and roofing. The platy texture acts as an antiblocking, antisticking agent. Rubber mold lubricant accounted for 4.8% of dry-ground mica use in 2000.

The plastics industry uses dry-ground mica as an extender and filler, especially in parts for automobiles for lightweight insulation to suppress sound and vibration. Mica is used in plastic automobile fascia and fenders as a reinforcing material, providing improved mechanical properties, increased strength, stiffness, and dimensional stability. Mica-reinforced plastics also have high-heat dimensional stability, reduced warpage, and the best surface properties of any filled plastic composite. In 2000, consumption of dry-ground mica in plastic applications accounted for 4.4% of the market, higher than the 2.9% consumed in 1999 (table 4).

Dry-ground mica is used in the production of rolled roofing

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and asphalt shingles where it serves as a surface coating to prevent sticking of adjacent surfaces. The coating is not absorbed by freshly manufactured roofing because mica's platy structure is unaffected by the acid in asphalt or by weathering conditions. As a rubber additive, mica reduces gas permeation and improves resiliency.

Mica is also used in decorative coatings on wallpaper, concrete, stucco, and tile surfaces. It is also used as an ingredient in some special greases, as a flux coating on welding rods, and in foundry applications as coatings for core and mold release compounds, mold washes, and facing agents.

Wet-ground mica, which retains the brilliancy of its cleavage faces, was used primarily in pearlescent paints by the automotive industry. Its reflective and refractive properties were also used in cosmetics where it was used as an ingredient in eye shadow, body and hair glitter, face makeup, and fingernail polish.

Stocks

Government stocks of mica in the NDS comprised stockpile-grade muscovite block, stained and better; muscovite film, 1st and 2nd qualities muscovite splittings; phlogopite block; and phlogopite splittings. NDS stocks of muscovite block, muscovite film, and muscovite and phlogopite splittings were available for sale from the Defense National Stockpile Center, Fort Belvoir, VA. Yearend 2000 stocks of various types of mica in the NDS are listed in table 2.

Reported yearend industry stocks of muscovite mica block (ruby and nonruby) decreased to 17.8 t in 2000 from 19.3 t in 1999. Industry stocks of muscovite and phlogopite mica splittings decreased to 404 t at yearend 2000 from 411 t at yearend 1999 (table 6).

Prices

Sheet mica prices vary with grade and can range from less than $1 per kilogram for low-quality mica to more than $2,000 per kilogram for the highest quality. The average values of muscovite sheet mica consumed in the United States in 2000 compared with the previous year were as follows: block (ruby and nonruby) increased to $22 per kilogram from $21 per kilogram in 1999, and muscovite splittings increased to $1.60 per kilogram from $1.51 per kilogram in 1999.

The average value of phlogopite block increased to $14.95 per kilogram in 2000 from $12.82 per kilogram in 1999. The average value of phlogopite splittings increased to $4.89 per kilogram in 2000 from $4.69 per kilogram in 1999.

In 2000, the average U.S. value of crude flake mica, including high-quality sericite, increased to $136 per ton (table 1). The average value for North Carolina flake mica decreased to $98 per ton in 2000. The value of dry-ground mica decreased 12% to average $169 per ton, and wet-ground mica also decreased 12% to average $751 per ton (table 1).

Foreign Trade

Demand for mica increased in U.S. and foreign markets in 2000. Foreign trade decreased, with the value of U.S. exports of mica decreasing by 9% to $22.4 million as the quantity decreased by 8% to 11,500 t. Imports of mica, however, increased by 12% to 34,000 t with the value of U.S. imports of mica increasing by 5% to $28.1 million (table 13).

Domestic ground mica exports increased to 8,880 t, up 1,560 t from that of 1999 (table 8). Exports of crude and rifted mica decreased to 651 t, primarily the result of decreased sheet mica sales from the NDS. Exports of worked mica sheet in 2000 increased by 27% to 1,070 t (table 9). The value of U.S. exports of worked mica sheet increased to $17.1 million, 2.8% higher than that of 1999.

India continued to supply the United States with essentially all of its supply of sheet and paper-quality scrap mica. Imports for consumption of unworked split block, film, splittings, and mica sheet catagorized as "Other," were about 9,784 t, 37% higher than that of 1999 (table 10).

About 22,100 t of ground mica were imported in 2000, mostly from Canada (table 11). Worked mica imports were 1,310 t, 27% lower than those of 1999 (table 12).

Outlook

The outlook for ground mica is for production growth of 1% to 3% per year. The major markets for ground mica—joint compounds and paints—are mature and relatively stable, and growth is tied to new housing starts and interest rates. To a lesser extent, widespread natural disasters also affect the market, creating immediate demand for residential building materials. Demand is also responsive to automobile production because interior and exterior parts typically contain dry-ground mica, and exterior surfaces are painted with wet-ground pearlescent pigments and mica-containing coatings.

In 2001 and 2002, domestic demand for crude and ground mica is expected to increase slightly. Demand for wet-ground mica is expected to improve significantly, at up to twice the rate of dry-ground mica, in the short term to meet increasing demand for plastic reinforcement fillers, nylon and polyester resins, polypropylene composites, pearlescent paints, and cosmetics. Markets for dry-ground mica are forecast to grow by as much as 3% per year through the year 2005, unless interest rates and prices rise sufficiently to slow demand for new housing and automobiles. Wet-ground mica is expected to show moderate growth in the long term as demand from the cyclical automotive industry, which uses increasing amounts of pearlescent paint and engineered mica-bearing plastics, increases.

Demand for block mica is expected to grow slowly over the next several years as demand increases in a few specialty markets. A shortage of high-quality block mica is expected to continue because of the generally low percentage of high-quality mica in currently (2000) mined deposits (pegmatites).

Consumption of mica splittings, the principal type of sheet mica consumed in the United States, decreased sharply throughout the 1960s and 1970s and leveled off in the 1980s and 1990s in the range of 700 to 1,000 t per year (t/yr). With no new uses and many substitute materials, no substantial growth is expected. Consumption of mica splittings is expected to remain in the range of 500 to 900 t/yr.

References Cited

AZCO Mining Inc., 2000a, Azco Mica Inc. produces cosmetic grade mica: Glendale, AZ, AZCO Mining Inc. news release, June 29, 1 p.

———2000b, Mining operations successfully completed at Black Canyon Mica Project—Commissioning Glendale plant: Glendale, AZ, AZCO Mining Inc. news release, February 4, 1 p.

Oglebay Norton Co., 2001, Oglebay Norton Company 2000 earnings increase to $3.00 per share—Fourth consecutive year of record revenues and EBITDA:

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Cleveland, OH, Oglebay Norton Co., February 5, 8 p.
Rieder, Milan, Cavazzini, Giancarlo, D'yakonov, Y.S., Frank-Kamenetskii, V.A., Gottardi, Glauco, Guggenheim, Stephen, Koval, P.V., Mueller, Georg, Neiva, A.M.R., Radoslovich, E.W., Robert, Jean-Louis, Sassi, F.P., Takeda, Hiroshi, Weiss, Zdenek, and Wones, D.R., 1998, Nomenclature of the micas (abstract): American Mineralogist, v.83, no. 11-12, November-December, p. 1366. (Abstract refers to American Mineralogist Special Features, Nomenclature of the micas, accessed September 25, 2001, at URL http://www.minsocam.org/MSA/AmMin/Special_Features/webmica3.pdf).
Zemex Corp., 2001, Zemex Corporation announces fiscal 2000 earnings results: Toronto, Canada, Zemex Corp. news release, March 21, 1 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Mica. Mineral Industry Surveys, annual.
Mica (Natural), Scrap and Flake. Ch. in Mineral Commodity Summaries, annual.
Mica (Natural), Sheet. Ch. in Mineral Commodity Summaries, annual.
Mica. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Mica. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Roskill Information Services Ltd. (London). The Economics of Mica (7th ed.), 1991.

TABLE 1
SALIENT MICA STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Production (sold or used by producers):						
Scrap and flake mica	thousand metric tons	95 r/	112 r/	87	95 r/	101
Value	thousands	$8,400 r/	$9,880 r/	$7,980 r/	$14,700 r/	$14,800
Ground mica	thousand metric tons	103	110	104	111	112
Value	thousands	$33,600	$37,000	$31,200	$36,700	$37,500
Prices, dollars per metric ton:						
Scrap and flake mica		$81	$83	$87	$148 r/	$136
Ground:						
Wet		$1,030	$1,080	$909	$849	$751
Dry		$182	$176	$179	$192	$169
Sheets, dollars per kilogram, muscovite and phlogopite:						
Block		$55	$28	$26	$20	$23
Splittings		$1.75	$1.69	$1.67	$1.67	$1.81
Consumption:						
Block, muscovite	metric tons	6	8	7	7	6
Value	thousands	$383	$249	$203	$139	$132
Splittings, all types	metric tons	859	736	763	786	583
Value	thousands	$1,510	$1,240	$1,270	$1,310	$1,060
Exports	metric tons	8,380	9,210	8,900	12,600	11,500
Imports	do.	24,700	28,900	27,400	30,200	34,000
World, production	do.	297,000 r/	308,000 r/	285,000 r/	279,000 r/	290,000 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits.

TABLE 2
STOCKPILE STATUS AND GOVERNMENT INVENTORIES FOR MICA, DECEMBER 31, 2000 1/

(Metric tons)

	Inventory (uncommitted)			
Material	Stockpile grade	Nonstockpile grade	Available for disposal	Fiscal year 1999 sales
Block:				
Muscovite, stained and better	171	--	171	132
Phlogopite	4	--	4	2
Film, muscovite (1st and 2d qualities)	--	--	--	--
Splittings:				
Muscovite	1,050	--	1,050	1,070
Phlogopite	233	--	233	--

-- Zero.
1/ Data are rounded to no more than three significant digits.

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TABLE 3
SCRAP AND FLAKE MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1999		2000	
	Quantity	Value	Quantity	Value
North Carolina	47	$4,550	47	$4,550
Other States 3/	49 r/	10,100 r/	54	10,200
Total	95 r/	14,700 r/	101	14,800

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes finely divided mica recovered from mica schist and high-quality sericite schist, and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.
3/ Includes Georgia, New Mexico, South Carolina, South Dakota, and Virginia.

TABLE 4
GROUND MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY END USE AN METHOD OF GRINDING 1/ 2/

	1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
End use:						
Joint cement	50	$9,760	$194	50	$8,670	$186
Paint	33	10,700	324	33	11,100	334
Plastics	3	1,460	450	5	2,140	436
Well-drilling mud	5	926	189	6	1,110	180
Other 3/	20	13,900	693	18	14,500	786
Total	111	36,700	329	112	37,500	333
Method of grinding:						
Dry	W	W	192	W	W	169
Wet	W	W	849	W	W	751

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Domestic and some imported scrap. Low-quality sericite is not included.
3/ Includes mica used for molded electrical insulation, roofing, rubber, textile and decorative coatings, welding rods, and miscellaneous.

TABLE 5
FABRICATION OF MUSCOVITE BLOCK MICA IN THE UNITED STATES, BY QUALITY 1/

(Metric tons)

	1999	2000
Good stained or better	0.394	0.323
Stained or lower 2/	6.230	5.620
Total	6.620	5.940

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes punch mica.

TABLE 6
CONSUMPTION AND STOCKS OF MICA SPLITTINGS IN THE UNITED STATES 1/

Year	Consumption		Stocks on December 31
	Quantity (metric tons)	Value (thousands)	(metric tons)
1999	786	$1,310	411
2000	583	1,060	404

1/ Data are rounded to no more than three significant digits.

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TABLE 7
BUILT-UP MICA SOLD OR USED IN THE UNITED STATES, BY PRODUCT 1/ 2/

	1999		2000	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Flexible plate (cold)	125	$875	61	$363
Heater plate	W	W	W	W
Molding plate	175	1,630	194	1,560
Segment plate	50	1,810	10	1,040
Tape	W	W	W	W
Other	157	1,890	72	508
Total	532	6,620	358	3,670

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Consists of alternating layers of binder and irregularly arranged and partly overlapped splittings.

TABLE 8
U.S. EXPORTS OF CRUDE AND RIFTED MICA, MICA POWDER, AND WASTE IN 2000, BY COUNTRY 1/

	Crude and rifted							
	Less than one dollar per kilogram		More than one dollar per kilogram		Powder		Waste	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	--	--	--	--	78	$50	--	--
Australia	--	--	--	--	49	27	--	--
Barbados	--	--	--	--	35	30	--	--
Belgium	26	$9	--	--	45	24	--	--
Brazil	16	6	--	--	32	69	--	--
Canada	13	4	--	--	5,030	1,720	859	$202
China	--	--	--	--	23	36	--	--
Colombia	--	--	11	$10	39	33	--	--
Congo (Brazzaville)	--	--	--	--	33	24	--	--
Costa Rica	25	9	--	--	--	--	--	--
Cote d'Ivoire	--	--	--	--	(2/)	7	--	--
Dominica	--	--	--	--	7	6	--	--
Dominican Republic	--	--	--	--	9	8	--	--
Ecuador	--	--	--	--	6	4	--	--
France	16	6	--	--	82	104	41	9
Germany	12	8	98	78	79	37	--	--
Guatemala	--	--	2	10	--	--	--	--
Hong Kong	12	4	--	--	48	29	--	--
Hungary	--	--	--	--	4	3	--	--
India	--	--	2	20	240	230	--	--
Indonesia	--	--	--	--	21	11	--	--
Ireland	34	4	--	--	42	21	--	--
Israel	--	--	--	--	78	26	--	--
Italy	--	--	--	--	652	383	--	--
Japan	--	--	71	85	337	303	--	--
Korea, Republic of	20	8	--	--	275	259	--	--
Malaysia	--	--	--	--	191	74	--	--
Mexico	24	8	1	7	632	495	--	--
Netherlands	--	--	--	--	184	132	39	21
New Zealand	--	--	(2/)	5	73	55	--	--
Niue	--	--	--	--	11	7	--	--
Pakistan	--	--	--	--	11	12	--	--
Qatar	--	--	9	79	--	--	--	--
Russia	--	--	--	--	19	5	--	--
Saudi Arabia	--	--	--	--	34	16	--	--
Singapore	52	18	--	--	--	--	--	--
South Africa	--	--	--	--	17	4	--	--
Spain	--	--	--	--	1	8	--	--
St. Lucia	--	--	--	--	4	3	--	--
Switzerland	--	--	11	7	--	--	--	--
Taiwan	--	--	--	--	146	112	--	--

See footnotes at end of table.

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TABLE 8--Continued
U.S. EXPORTS OF CRUDE AND RIFTED MICA, MICA POWDER, AND WASTE IN 2000, BY COUNTRY 1/

Country	Crude and rifted: Less than one dollar per kilogram, Quantity (metric tons)	Crude and rifted: Less than one dollar per kilogram, Value (thousands)	Crude and rifted: More than one dollar per kilogram, Quantity (metric tons)	Crude and rifted: More than one dollar per kilogram, Value (thousands)	Powder, Quantity (metric tons)	Powder, Value (thousands)	Waste, Quantity (metric tons)	Waste, Value (thousands)
Tanzania	--	--	--	--	3	$7	--	--
Thailand	--	--	--	--	29	17	--	--
Trinidad and Tobago	--	--	--	--	4	8	--	--
United Kingdom	194	$71	3	$35	224	169	--	--
Venezuela	--	--	(2/)	7	45	36	--	--
Total	442	151	209	343	8,880	4,610	939	$232

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. EXPORTS OF WORKED MICA IN 2000, BY COUNTRY 1/

Country	Plates, sheets: Quantity (metric tons)	Plates, sheets: Value (thousands)	Other: Quantity (metric tons)	Other: Value (thousands)
Argentina	25	$124	--	--
Australia	29	788	--	--
Bahamas, The	1	15	1	$16
Bahrain	1	23	--	--
Bangladesh	(2/)	4	--	--
Barbados	8	49	2	24
Belgium	9	231	--	--
Brazil	60	1,160	6	180
Canada	124	3,290	85	1,890
Chile	72	216	--	--
China	3	40	--	--
Colombia	13	245	--	--
Costa Rica	1	10	2	27
Denmark	(2/)	3	--	--
Dominican Republic	1	4	--	--
El Salvador	2	6	--	--
France	10	147	14	91
Gambia, The	(2/)	8	--	--
Germany	29	265	(2/)	23
Guatemala	1	3	--	--
Guyana	(2/)	5	--	--
Honduras	(2/)	5	--	--
Hong Kong	6	48	(2/)	6
India	21	416	(2/)	3
Indoneisa	(2/)	4	--	--
Ireland	2	20	--	--
Israel	6	61	1	27
Italy	22	444	1	22
Jamaica	15	109	--	--
Japan	3	94	1	51
Korea, Republic of	3	28	1	21
Mexico	159	1,610	74	2,290
Netherlands	1	12	--	--
Netherlands Antilles	(2/)	8	1	8
Peru	61	437	--	--
Qatar	5	15	--	--
Saudi Arabia	1	10	--	--
Singapore	21	110	--	--
South Africa	(2/)	28	--	--
Spain	(2/)	3	(2/)	9
Sweden	1	9	--	--

See footnotes at end of table.

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TABLE 9--Continued
U.S. EXPORTS OF WORKED MICA IN 2000, BY COUNTRY 1/

Country	Plates, sheets		Other	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Switzerland	48	$580	18	$136
Taiwan	5	95	10	202
Trinidad and Tobago	4	17	2	5
Turkey	1	21	--	--
Turks and Caicos Islands	--	--	(2/)	5
United Arab Emirates	1	19	--	--
United Kingdom	49	1,060	3	98
Venezuela	18	66	--	--
Total	843	12,000	223	5,130

-- Zero.
1/ Data are rounded to no more than three significant digits; may add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND RIFTED MICA IN 2000, BY COUNTRY 1/

Country	Split block		Splittings		Other			
					Less than $1 per kilogram		More than $1 per kilogram	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	--	--	--	--	--	--	(2/)	$4
Canada	--	--	--	--	130	$18	--	--
China	--	--	--	--	1,950	237	(2/)	$10
Cote d'Ivoire	--	--	--	--	122	15	--	--
Finland	--	--	--	--	309	60	2	187
India	107	$115	4,020	$1,240	2,880	500	274	486
Madagascar	(2/)	3	--	--	--	--	--	--
Total	107	118	4,020	1,240	5,380	830	277	686

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF MICA POWDER AND WASTE IN 2000, BY COUNTRY 1/

Country	Powder		Waste	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	1,100	$1,670	--	--
Austria	22	6	--	--
Brazil	--	--	20	$26
Canada	19,700	7,270	--	--
China	61	13	--	--
Finland	350	30	--	--
France	--	--	36	19
Germany	46	290	--	--
India	138	54	725	395
Italy	19	12	--	--
Japan	569	3,380	--	--
Madagascar	--	--	18	19
Norway	37	26	--	--
Peru	(2/)	2	--	--
Total	22,100	12,800	799	459

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S Census Bureau.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF WORKED MICA IN 2000, BY COUNTRY 1

Country	Plates, sheets		Other	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	3	$71	--	--
Austria	3	58	5	$118
Belgium	598	6,030	--	--
Brazil	59	341	--	--
Canada	1	18	(2/)	29
China	123	359	24	219
Colombia	52	122	--	--
Denmark	135	338	--	--
France	23	153	1	37
Germany	(2/)	18	2	95
Hong Kong	1	5	5	46
India	50	735	52	885
Ireland	--	--	(2/)	3
Japan	4	115	11	277
Korea, Republic of	15	86	32	64
Sweden	--	--	(2/)	10
Switzerland	68	1,370	--	--
Taiwan	(2/)	3	3	13
Turkey	29	143	--	--
United Kingdom	9	232	(2/)	25
Total	1,170	10,200	135	1,820

-- Zero.
1/ Data are rounded to no more than three significant digits; may add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 13
SUMMATION OF U.S. MICA TRADE DATA 1/

	Scrap and flake mica				Sheet mica			
	Powder		Waste		Unworked		Worked	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Exports:								
1999	7,320	$4,010	3,950	$1,290	452	$2,150	840	$16,600
2000	8,880	4,610	1,380	383	209	343	1,070	17,100
Imports for consumption:								
1999	20,600	11,300	5,070	1,150	2,770	1,520	1,780	12,800
2000	22,100	12,800	6,180	1,290	4,400	2,040	1,310	12,000

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 14
MICA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Argentina:					
Sheet e/	297 4/	300	300	300	300
Waste, scrap, etc.	1,840	3,228	3,200 e/	3,097 r/	3,100
Brazil	7,000	4,000	4,000 r/	5,000 r/	5,000
Canada e/	17,500	17,500	17,500	17,500	17,500
France e/	8,000	8,000	10,000	10,000	10,000
India:					
Crude	1,894	1,794	1,489	1,500 e/	1,500
Scrap and waste	1,413	1,128	966	1,000 e/	950
Total	3,307	2,922	2,455	2,500 e/	2,450
Iran 5/	3,000 e/	3,000 e/	1,084 r/	1,425 r/	2,000
Korea, Republic of (all grades)	35,923	34,489	38,459	24,733 r/	30,000
Madagascar (phlogopite)	450 e/	603	212 r/	491 r/	491
Malaysia	5,501	5,708	3,642	3,675 r/	3,700
Mexico (all grades)	4,273	975	890	971 r/	1,058 4/
Morocco e/	-- r/	-- r/	-- r/	-- r/	--
Peru e/	100	100	100	100	100
Russia e/	100,000	100,000	100,000	100,000	100,000
Serbia and Montenegro e/	200	200	150	50	100
South Africa (ground and scrap)	1,515	1,423	1,556	1,010 r/	707 4/
Spain e/	2,507 4/	2,500	2,500	2,500	2,500
Sri Lanka (scrap)	2,400	3,700 r/	2,800 r/	1,425 r/	1,500
Taiwan	8,510	7,806	7,750	7,000 r/ e/	7,000
United States (scrap and flake) 6/	94,700 r/	112,000 r/	87,000 r/	95,400 r/	101,000 4/
Zimbabwe	42 r/	30	1,309	1,300 e/	1,300
Grand total	297,000 r/	308,000 r/	285,000 r/	279,000 r/	290,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 30, 2001.

3/ In addition to the countries listed, China, Norway, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Year beginning March 21 of that stated.

6/ Excludes, if any, U.S. production of low-quality sercite and sheet mica.

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MOLYBDENUM

By John W. Blossom

Domestic survey data and tables were prepared by Barbara J. McNair, statistical assistant and the world production table was prepared by Linder Roberts, international data coordinator.

Molybdenum is a refractory metallic element used principally as an alloying agent in steel, cast iron, and superalloys to enhance hardenability, strength, toughness, and wear and corrosion resistance. To achieve desired metallurgical properties, molybdenum, primarily in the form of molybdic oxide or ferromolybdenum, is frequently used in combination with or added to chromium, columbium, manganese, nickel, tungsten, or other alloy metals. The versatility of molybdenum in enhancing a variety of alloy properties has ensured it a significant role in contemporary industrial technology, which increasingly requires materials that are serviceable under high stress, expanded temperature ranges, and highly corrosive environments. Moreover, molybdenum finds significant usage as a refractory metal in numerous chemical applications, including catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitution, has resulted in demand that is expected to grow at a greater rate than that of most other alloying metals.

Distribution of molybdenum reserves and productive capacity was concentrated in a few countries of the world. World mine output was estimated to be 129,000 metric tons (t) (molybdenum contained in concentrate), of which, in descending order of production, the United States, Chile, China, Peru, Mexico, and Canada provided 92%. These countries also possessed about 90% of the estimated 12 million metric tons of molybdenum in the world reserve base. [All units are metric tons of contained molybdenum unless otherwise noted.]

Production

Domestic production data for molybdenum were derived by the U.S. Geological Survey by means of three separate voluntary surveys. These surveys are Molybdenum Ore and Concentrate (annual), Molybdenum Concentrate (monthly), and Molybdenum Products and Molybdenum Concentrates (monthly). Surveys are sent to all operations that produce molybdenum ore and products. All eight operations to which surveys were sent responded, representing 100% of the U.S. production shown in table 1.

In 2000, U.S. mine production of molybdenum concentrate was 41,100 t, a decrease from 42,400 t in 1999. World mine production of molybdenum concentrate increased to 129,000 t in 2000 from 128,000 t in 1999. U.S. share of world production was 31% in 2000, 33% in 1999. Net production of molybdenum products increased by 500 t in 2000. (See tables 1, 2, 7-8.)

Thompson Creek Mining Company announced in January 2001, that it would curtail operations at the Thompson Creek mine near Challis, ID (Thompson Creek Mining Company, 2001). This reduction in mining activity was necessitated by near-record-low prices in the molybdenum industry, reduction in demand due to a slowing U.S. economy, and the continuing export by China of increasing quantities of molybdenum products into the world market, according to Thompson Creek Mining.

The mine planned to produce 2.7 million kilograms in 2001, which was about one-half of its production rate in 2000 and less than one-third of its capacity. Thompson Creek said it would continue to supply long-term customers and will emphasize sales of value-added products.

The new mine plan reportedly was to entail the elimination of 65 jobs out of a work force of 125. Severed employees were to continue to receive salary and benefits through March 17, 2001. Thompson Creek Mining Company is a subsidiary of Thompson Creek Metals Co. The company also operates the Endako molybdenum mine in Canada as well as the Langeloth metallurgical processing facility in Pennsylvania.

Molybdenum in the 20th Century

At the beginning of the 20th century, there was little demand for molybdenum minerals, except for limited use in the manufacture of chemical reagents. One pound of contained metallic molybdenum in molybdenite ore was worth about $0.10. Most bonanza ores were exhausted by 1900, and molybdenum mining's future rested squarely on its ability to mass mine large deposits of low-grade ores and to concentrate them economically. Flotation separation technology enabled this to be done. Average annual U.S. molybdenum production during the first decade of the century was about 40 metric tons per year; however, production was reported only for 1901-1903.

By 1910, the price of molybdenum was nudging $2.20 per kilogram, as the molybdenum market was slowly coming to life. As World War I raged in Europe in 1914, German, British, French, and Russian armament manufacturers competed to buy all available molybdenum from the only European source, Kven Mine and mill at Knaben, Norway. U.S. production and price of molybdenum peaked at 391 tons in 1918 with the end of World War I. New uses in the steel and chemical industry grew with expanding population. The U.S. production of molybdenum reached a peak of 68,400 tons in 1980. The lowest U.S. production since 1980 was 15,200 tons in 1993. At the end of the 20th century, U.S. production was trending downward. Molybdenum was being used in many more applications, such as stainless steel, catalysts and lubricants, with reported consumption exceeding 20,000 tons per year in the last decade of the century.

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Consumption

In 2000, consumption of molybdenum concentrate was 33,800 t, a decreased 700 t compared with that of 1999. Domestic mine production of molybdenum concentrate was roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. Technical-grade molybdic oxide consumption decreased by about 3% in 2000 compared with that of 1999. Oxide was the chief form of molybdenum used by industry, particularly in stainless and alloy steel, cast iron, and superalloys. However, ferromolybdenum comprised 67% of the molybdenum-bearing forms used to make steel, a 1% decrease from that of 1999. Some of the oxide was, however, converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder. (See tables 1, 3.)

Stocks

In 2000, producer plus consumer industry stocks were 11,400 t, a decrease of 600 t compared with those of 1999. Inventories of molybdenum in concentrate at mine and plant decreased by about 550 t. Producer stocks of molybdenum in products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, increased by about 20 t. Consumer stocks of molybdenum contained in various materials decreased by 40 t compared with those of 1999. Stocks of 11,400 t represented about a 35-week supply. Supply is calculated as reported stocks (table 1) divided by annual consumption (table 3).

Prices

Prices are from Platt's Metals Week (2000) and are in U.S. dollars per kilogram of contained molybdenum. At the beginning of 2000, the prices were molybdenum molybdic oxide (MoX), $5.534 and ferromolybdenum (FeMo), $7.716. At the beginning of the second quarter, the prices were MoX, $5.567 and FeMo, $7.606. At the start of the third quarter, the prices were MoX, $6.228 and FeMo, $7.937. At the start of the fourth quarter, the prices were MoX, $5.578 and FeMo, $7.606. At the end of the fourth quarter, the prices were MoX, $4.806 and FeMo, $6.779. The annual average prices were MoX, $5.638 and FeMo, $7.625.

Foreign Trade

Exports of molybdenum in concentrate and in molybdic oxide were about 15% lower than those of 1999; molybdenum concentrate exports were about 58% of domestic mine production. About 90% of reported exports of concentrates went to Belgium, Canada, Japan, the Netherlands, and the United Kingdom. In 2000, molybdenum exports collectively contained about 27,600 t of molybdenum and were valued at $159 million, a 15% decrease from $186 million in 1999.

The United States imported about 13,600 t of molybdenum contained in various materials, which was about 700 t more than those imported in 1999. Total value of all forms of molybdenum imported increased from $104 million in 1999 to $111 million in 2000. In terms of value, the major form imported was ferromolybdenum. Major import sources, in descending order of quantity imported, were United Kingdom, Chile, and China. (See tables 4, 5, 6.)

World Review

Capacity.—As of December 31, U.S. rated capacity for mines and mills was estimated to be 70,000 metric tons per year of contained metal. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity included operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Reserves.—With a reserve base of molybdenum estimated to be 5.4 Mt, the United States had 45% of the world molybdenum reserve base. About 90% of U.S. reserves was in large porphyry or disseminated deposits mined or anticipated to be mined primarily for molybdenum; these deposits were in Alaska, Colorado, Idaho, Nevada, New Mexico, and Utah. Other molybdenum sources contribute insignificantly to U.S. reserves.

Most Canadian reserves of molybdenum are in British Columbia. Other Canadian reserves were associated with molybdenum and copper-molybdenum porphyry deposits in British Columbia and with minor sources in New Brunswick and Quebec.

Molybdenum reserves in Central America and South America were associated mainly with large copper porphyry deposits. Of several such deposits in Chile, the Chuquicamata and El Teniente deposits were among the world's largest and accounted for 85% of molybdenum reserves in Chile. Mexico and Peru had substantial reserves. La Caridad deposit in Mexico was a large producer. Numerous other copper porphyries that may contain recoverable quantities of molybdenum have been identified in Central America and South America. Many of these deposits were being actively explored and evaluated and could substantially add to reserves in the future.

Reserves of molybdenum in China and the Commonwealth of Independent States were estimated to be substantial, but definitive information about the current sources of supply or prospects for future development in these two areas was lacking.

Outlook

Because of abundant resources and adequate production capacity in China, Chile, the United States and other countries, the future requirement for molybdenum should be readily met by the world producers. The principal use for molybdenum will continue to be in chemicals/catalysts and as an additive in steel manufacturing in general, most importantly alloy and stainless steel. Strong growth in production of stainless steel and superalloys can be expected in the near term with generally healthy economic conditions over the next few years.

Reference Cited

Thompson Creek Mining Company, 2001, Thompson Creek Mining Company reduces mine production: Clayton, ID, Thompson Creek Mining Company news release, January 16, 1 p.

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SOURCES OF INFORMATION

U.S. Geological Survey Publications

Molybdenum. Ch. in Minerals Commodity Summaries, annual.
Molybdenum. Ch. in Minerals Yearbook, annual.
Molybdenum. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Molybdenum. Reported monthly and annually in Mineral Industry Surveys.

Other

American Bureau of Metal Statistics. Nonferrous Metal Data.
American Metal Market (daily paper).
Annual reports of various companies.
Canadian Mining Journal.
Engineering and Mining Journal.
Metal Bulletin (London).
Mining Engineering.
Mining Journal (London).
Mining Voice.
Molybdenum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platt's Metals Week.
Skillings Mining Review.
The Northern Miner.

TABLE 1
SALIENT MOLYBDENUM STATISTICS 1/

(Metric tons, of contained molybdenum, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Concentrate:					
Production	56,000 r/	60,100 r/	53,300	42,400 r/	41,100
Shipments	35,800 r/	32,100 r/	52,100	42,800 r/	35,600
Value, shipments thousands	$456,000	$406,000	$200,000	$251,000 r/	$232,000
Reported consumption	24,500	24,300	35,900	34,500	33,800
Imports for consumption	5,480	6,330	6,570	6,390	6,120
Stocks, December 31:					
Concentrate, mine and plant	2,470	3,660	6,270	4,580	4,030
Product producers 2/	5,780	6,500	7,780	5,340	5,360
Consumers, by end use	1,650	1,150	2,170	2,130	2,040
Total	9,900	11,300	16,200	12,000	11,400
Primary products:					
Production	46,300	48,000	57,200	39,800	42,900
Shipments	24,100	25,900	38,000	39,000	34,600
Reported consumption, by end use	20,900	20,000	18,800	18,700 r/	18,600
World, mine production	127,000 r/	138,000 r/	135,000	128,000 r/	129,000 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes technical and purified molybdic oxide, briquets, ferromolybdenum, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, sodium molybdate, calcium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF MOLYBDENUM PRODUCTS IN THE UNITED STATES 1/

(Metric tons of contained molybdenum)

	Metal powder		Other 2/		Total	
	1999	2000	1999	2000	1999	2000
Received from other producers	--	2	19,100	16,100	19,100	16,100
Gross production during year	4,090	5,180	35,700	37,700	39,800	42,900
Molybdenum products used to make other products	2,200	3,000	18,300	20,200	20,500	23,200
Net production	1,880	2,190	17,400	17,500	19,200	19,700
Shipments	580	730	38,500	33,900	39,000	34,600
Producer stocks, December 31	158	259	5,180	5,100	5,340	5,360

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes ferromolybdenum, molybdic oxides, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, calcium molybdate, sodium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

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TABLE 3
U.S. REPORTED CONSUMPTION, BY END USES, AND CONSUMER STOCKS OF MOLYBDENUM MATERIALS 1/

(Kilograms, contained molybdenum)

End use	Molybdic oxides	Ferro-molyb-denum 2/	Ammonium and sodium molybdate	Molyb-denum scrap	Other	Total
1999:						
Steel:						
Carbon	434,000 r/	335,000 r/	--	--	68,500	838,000 r/
High-strength low-alloy	455,000 r/	133,000 r/	--	--	--	588,000 r/
Stainless and heat-resisting	3,440,000 r/	694,000 r/	--	--	55,400 r/	4,190,000 r/
Full alloy	1,750,000 r/	2,110,000 r/	--	--	27,900	3,890,000 r/
Tool	900,000 r/	93,400 r/	--	--	17,800	1,010,000 r/
Total	6,980,000 r/	3,360,000 r/	--	--	170,000 r/	10,500,000 r/
Cast irons (gray, malleable, ductile iron)	177,000 r/	830,000 r/	--	--	179,000 r/	1,190,000 r/
Superalloys	994,000	W	--	(3/)	984,000 r/	1,980,000 r/
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	37,900 r/	--	--	928 r/	38,900 r/
Other alloys	--	74,500 r/	--	--	77,900 r/	152,000 r/
Mill products made from metal powder 4/	--	--	--	--	2,400,000 r/	2,400,000 r/
Cemented carbides and related products 5/	--	--	--	--	80 r/	80 r/
Chemical and ceramic uses:						
Pigments	--	--	W	--	W	W
Catalysts	974,000	--	W	--	W	974,000
Other	W	--	--	--	17,400	17,400
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	234,000 r/	234,000 r/
Other	13,100 r/	48,400	1,130,000 r/	--	53,400 r/	1,250,000 r/
Grand total	9,140,000 r/	4,350,000 r/	1,130,000 r/	--	4,120,000 r/	18,700,000 r/
Stocks, December 31, 1999	991,000 r/	224,000 r/	36,500 r/	19,200 r/	856,000 r/	2,130,000 r/
2000:						
Steel:						
Carbon	425,000	347,000	--	--	21,800	794,000
High-strength low-alloy	989,000	135,000	--	--	303,000	1,430,000
Stainless and heat-resisting	3,070,000	485,000	--	--	104,000	3,660,000
Full alloy	1,380,000	2,220,000	--	--	47,500	3,650,000
Tool	1,020,000	398,000	--	--	55,400	1,470,000
Total	6,880,000	3,590,000	--	--	532,000	11,000,000
Cast irons (gray, malleable, ductile iron)	W	523,000	--	--	27,000	550,000
Superalloys	865,000	W	--	(3/)	1,020,000	1,880,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	41,500	--	--	916	42,400
Other alloys	W	63,300	--	--	94,000	157,000
Mill products made from metal powder 4/	W	--	--	--	2,190,000	2,190,000
Cemented carbides and related products 5/	--	--	--	--	154	154
Chemical and ceramic uses:						
Pigments	W	--	241,000	--	W	241,000
Catalysts	985,000	--	W	--	W	985,000
Other	W	--	--	--	W	W
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	263,000	263,000
Other	147,000	51,100	1,080,000	--	21,600	1,300,000
Grand total	8,880,000	4,270,000	1,330,000	--	4,150,000	18,600,000
Stocks, December 31, 2000	928,000	197,000	39,700	19,900	855,000	2,040,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and uspecified uses: Other." -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes calcium molybdate.

3/ Included with "Other" of "Superalloys" category.

4/ Includes construction, mining, oil and gas, and metal working machinery.

5/ Includes ingot, wire, rod, and sheet.

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TABLE 4
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS No.	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Belgium		91	$688	37	$206
Brazil		10	105	2	21
Canada		546	4,920	711	4,940
Germany		2	33	--	--
Japan		153	1,260	188	1,880
Mexico		294	1,250	191	1,040
United Kingdom		1	8	1	8
Other		28	246	55	473
Total		1,130	8,510	1,190	8,560
Molybdates all, contained weight:	2841.70.0000				
Australia		4	42	5	64
Brazil		1	4	2	45
Canada		497	2,090	475	2,240
China		(2/)	6	(2/)	12
Colombia		2	11	2	17
Honduras		2	22	2	22
Japan		287	1,940	202	1,850
Korea, Republic of		94	927	44	324
Mexico		47	287	30	1,380
Netherlands		319	1,260	251	1,080
Singapore		37	335	17	91
Taiwan		2	32	16	106
Thailand		2	31	1	19
Venezuela		--	--	8	49
Other		10	72	22	225
Total		1,300	7,050	1,080	7,530
Ferromolybdenum, contained weight: 3/	7202.70.0000				
Australia		2 r/	20 r/	1	16
Canada		935 r/	5,020 r/	920	4,980
China		336 r/	3,270 r/	--	--
Japan		83 r/	3,230	95	3,420
Korea, Republic of		18 r/	167	4	37
Mexico		132 r/	653 r/	214	1,470
Venezuela		(2/)	8	--	--
Other		--	--	(2/)	12
Total		1,510 r/	12,400	1,230	9,940
Powder, gross weight:	8102.10.0000				
Brazil		18	536	7	263
Canada		3	116	3	123
France		3	111	3	58
Germany		54	1,290	51	1,430
India		2	76	2	124
Italy		(2/)	3	10	294
Japan		11	332	31	612
Mexico		1	42	3	115
Spain		6	167	7	188
Sweden		50	765	40	919
Switzerland		6	123	(2/)	3
Taiwan		186	3,470	88	1,530
United Kingdom		(2/)	20	3	113
Other		22	491	52	1,170
Total		362	7,540	300	6,940

See footnotes at end of table.

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TABLE 4--CONTINUED
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS No.	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Molybdenum unwrought, gross weight:	8102.91.0000				
Australia		2	$51	--	--
Brazil		(2/)	2	--	--
Canada		16	411	19	$364
China		(2/)	7	39	616
France		9	147	1	30
Germany		3	58	35	408
Japan		44	675	4	57
Korea, Republic of		3	123	7	263
Mexico		(2/)	26	6	108
Netherlands		1	50	16	253
Sweden		(2/)	23	1	26
United Kingdom		39	407	68	1,030
Other		50	445	32	392
Total		167	2,430	228	3,550
Molybdenum wrought, gross weight:	8102.92.0000				
Brazil		(2/)	33	1	42
Canada		34	961	23	713
France		2	359	2	210
Germany		6	588	7	361
India		(2/)	36	1	99
Italy		(2/)	3	(2/)	10
Japan		30	2,020	63	3,820
Korea, Republic of		2	229	2	180
Mexico		1	120	1	90
Netherlands		5	125	(2/)	11
United Kingdom		49	2,490	76	3,440
Other		18	1,090	9	636
Total		147	8,050	185	9,610
Wire, gross weight:	8102.93.0000				
Argentina		(2/)	17	(2/)	23
Belgium		3	3,760	9	355
Brazil		38	1,440	13	645
Canada		2	180	3	249
France		5	323	7	368
Germany		25	1,600	15	850
Hungary		53	2,980	44	3,710
India		29	1,320	22	1,010
Indonesia		1	92	10	427
Italy		2	109	2	89
Japan		2	179	5	318
Korea, Republic of		17	810	8	406
Mexico		2	282	1	136
South Africa		(2/)	58	(2/)	17
Spain		3	125	1	52
Sweden		7	282	2	73
Taiwan		(2/)	19	(2/)	8
United Kingdom		(2/)	81	1	83
Other		11	278	7	478
Total		200	13,900	150	9,300

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Ferromolybdenum contains about 60% to 65% molybdenum.

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED AND OTHER CONCENTRATES), BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons, contained molybdenum)	Value (thousands)	Quantity (metric tons, contained molybdenum)	Value (thousands)
Australia	41	$422	31	$374
Belgium	4,740	18,800	5,120	21,100
Brazil	66	723	31	386
Canada	1,350	6,720	1,420	6,240
Chile	2,420	6,910	35	263
China	1,190	2,070	795	1,540
Germany	122	629	672	3,080
India	102	511	1	10
Italy	264	1,580	90	754
Japan	2,320	14,300	3,100	16,800
Korea, Republic of	109	720	16	243
Mexico	129	718	62	238
Netherlands	8,620	44,500	8,780	37,700
Sweden	613	3,450	454	2,720
United Kingdom	5,530	25,900	2,910	11,400
Other	231	1,250	100	774
Total	27,900	129,000	23,600	104,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM 1/

		1999			2000		
Item	HTS No.	Gross weight (metric tons)	Contained molybdenum	Value (thousands)	Gross weight (metric tons)	Contained molybdenum	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	9,020	5,710	$33,200	6,900	4,340	$25,800
Molybdenum ore and concentrates, other	2613.90.0000	1,310	680	2,450	3,440	1,780	9,660
Molybdenum oxides and hydroxides	2825.70.0000	746	NA	5,100	1,210	NA	7,400
Molydates of ammonium	2841.70.0000	1,240	730	6,650	2,270	1,310	12,200
Molybdates all others	2841.70.5000	181	83	727	332	236	1,170
Molybdenum orange	3206.20.0000	1,550	NA	6,720	1,620	NA	7,320
Ferromolybdenum	7202.70.0000	8,350	5,160	37,300	8,310	5,310	35,600
Molybdenum powders	8102.10.0000	114	106	3,240	137	125	3,770
Molybdenum unwrought	8102.91.1000	14	13	542	16	16	328
Molybdenum waste and scrap	8102.91.5000	470	463	6,130	475	466	5,670
Molybdenum wire	8102.93.0000	8	NA	638	17	NA	894
Molybdenum other	8102.99.0000	11	NA	1,690	7	NA	1,600
Total		23,000	12,900	104,000	24,700	13,600	111,000

NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 7
MOLYBDENUM-PRODUCING MINES IN THE UNITED STATES IN 2000

State and mine	County	Operator	Source of molybdenum
Arizona:			
Bagdad	Yavapai	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated.
Sierrita	Pima	do.	Do.
Colorado:			
Henderson	Clear Creek	do.	Molybdenum ore, concentrated.
Idaho:			
Thompson Creek	Custer	Thompson Creek Metals Co.	Do.
Montana:			
Continental	Silver Bow	Montana Resources Inc.	Copper-molybdenum ore, concentrated.
New Mexico:			
Chino	Grant	Phelps Dodge Corp.	Do.
Questa	Taos	Unocal Corp	Molybdenum ore, concentrated.
Utah:			
Bingham Canyon	Salt Lake	Kennecott Utah Copper Corp.	Copper-molybdenum ore, concentrated.

TABLE 8
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained molybdenum)

Country 3/	1996	1997	1998	1999	2000 e/
Armenia e/	1,800 4/	1,800	2,500	2,500	2,700
Canada	8,789	7,612	7,991	6,250 r/	6,833 p/ 4/
Chile	17,415	21,339	25,298	27,270 r/	29,100
China e/	29,600	33,300	30,000	29,700 r/	28,900
Iran e/	560	600	1,400 r/	1,600 r/	1,600
Kazakhstan e/	100	100	100	110	600
Kyrgyzstan	NA	NA	225 e/	250	250
Mexico	4,210	4,842	5,949	7,961 r/	6,886 p/ 4/
Mongolia	2,201	1,992	1,993	1,953	1,336 4/
Peru	3,711	3,835	4,344	5,470 r/	7,193 4/
Russia e/	2,000	2,000	2,000	2,400	2,400
United States	56,000 r/	60,100 r/	53,300	42,400 r/	41,100
Uzbekistan e/	500	500	350 r/	350 r/	350
Total	127,000 r/	138,000 r/	135,000	128,000 r/	129,000

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 11, 2001.
3/ In addition to the countries listed, North Korea, Romania, and Turkey are believed to produce molybdenum, but output is no reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.
4/ Reported figure.

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NICKEL

By Peter H. Kuck

Domestic survey data and tables were prepared by Barbara J. McNair, statistical assistant, and world production tables were prepared by Glenn J. Wallace, international data coordinator.

Producers continued to commission new mines and add capacity because of optimistic forecasts for long-term growth in demand for stainless steel and nickel-based batteries. More than 280,000 metric tons (t) of capacity (on a contained nickel basis) were scheduled to come on-stream between 2001 and 2007. In Western Australia, three new laterite mines were commissioned between 1998 and 2000, and at least three others were in various stages of development (Western Australian Department of Resources Development, 1999, p. 3-18; Griffiths, 2000). The three new laterite mines were refining the nickel on-site. However, two new sulfide mines in Western Australia were shipping concentrates or matte to Outokumpu Oyj's recently expanded smelting and refining complex in Finland. In addition to the expansion in Australia, new mining projects were at various stages of development in Brazil, Canada, Indonesia, New Caledonia, the Philippines, and Venezuela. Exports of primary nickel from Russia were up about 6% from 1999 levels. Russian exports exceeded demand inside the country by more than 9 to 1. Russian consumption of nickel has been severely depressed for the past 4 years largely because the former Soviet stainless steel industry has had problems shifting to a market-economy mode.

Stainless steel accounted for more than 60% of nickel consumption in the world. In the United States, however, this percentage was considerably lower and was closer to 40% because of the relatively large number of specialty metal industries in the country. Specialty uses included superalloys and other aerospace alloys, high-temperature nickel-chromium alloys, electrolytic plating, electroless plating, cupronickel alloys, and naval brasses.

Nickel in excess of 8% is needed to produce the austenitic structure in 300-series stainless steels. The nickel content of some austenitic grades can be as high as 22%. Duplex (ferritic-austenitic) steels generally contain only 2.5% to 5.0% nickel (Ni). Sometimes, smaller amounts of nickel (0.2% to 3.8%) are incorporated into low alloy steels to improve their resistance to atmospheric corrosion.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—For more than a decade, the U.S. Department of Energy (DOE) has been exploring ways of reusing nickel metal scrap contaminated with trace amounts of natural and manmade radioactive isotopes. DOE has some 6,000 t of volumetrically contaminated nickel stored at the East Tennessee Technology Park in Oak Ridge, TN. "Volumetrically contaminated" describes metal that has radioactive contamination dispersed throughout the mass of the

Nickel in the 20th Century

In 1900, refineries in New Jersey and New York recovered a total of 4 metric tons of nickel from byproduct matte produced at the Mine Lamotte lead smelter in Missouri. The bulk of U.S. nickel consumption, however, was met by cobalt-copper-nickel matte imported from Canada and processed into nickel oxide or metallic nickel at Bayonne and Camden, NJ. The nickel smelter at Sudbury, Ontario, shipped 23,287 tons of ore and matte, containing about 3,100 tons of nickel, to the United States in 1900. France and the German Empire were Canada's biggest competitors for nickel production between 1890 and 1905. Both European producers were heavily dependent on matte and ore from New Caledonia, where nickel laterite mining had begun in 1875. The most important use was the manufacture of nickel steel, a family of alloy steels containing 3% to 25% nickel. By 1900, nickel steel was being fabricated into armor plate, gun turrets, propeller shafts, crank shafts, and a variety of other parts for naval vessels. Shipbuilders also found that nickel-bronzes and nickel-brasses were relatively resistant to saltwater corrosion and made good vessel parts. Other important end uses were coins, cutlery, and plating. Most of the cutlery was being fabricated from German silver, a family of copper-zinc-nickel alloys.

Nickel had been a strategic and critical material in every major conflict fought by the United States since 1900, with the U.S. Government having to allocate or ration the metal in almost every instance. World War I caused world production of nickel steel to soar. The development of stainless steel between 1905 and 1912 further accelerated demand for nickel. Nickel had become a vital aerospace material. The discovery of nickel-base superalloys during the 1930s permitted the development of jet aircraft engines and rocket engines during World War II. In the 1980s, soaring sales of mobile telephones, the invention of the laptop computer, and a resurgence of interest in electric vehicles led to the development of the nickel-metal hydride battery. In 2000, Russia, Canada, and Australia were the largest nickel-mining countries. The United States had never been a major source of nickel ore. Japan was the largest nickel-consuming country in the world, followed by the United States and Germany. The United States used 60,300 tons of primary nickel, or about 39% of the 156,000 tons imported, to produce a variety of stainless and alloy steels. Production of superalloys and various nickel-base alloys accounted for another 36% of primary nickel. The remaining 25% was divided largely between batteries, catalysts, coinage, and plating.

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metal, as opposed to a surface coating of contamination. The principal contaminants in the Oak Ridge nickel are reportedly technetium-99 (a beta emitter with a half-life of 211,000 years) and uranium-235. The nickel is a vestige of the U.S. Government's nuclear weapons programs.

In 1996, DOE awarded a contract to British Nuclear Fuels Ltd. (BNFL) to clean up a defunct gaseous diffusion plant at the Oak Ridge site in the technology park. As part of the contract, BNFL was to decontaminate nickel metal used in the plant operations so that it could be commercially recycled. The DOE plan, however, ran into opposition from several industry and community groups. The American Iron and Steel Institute (AISI), other members of the Metals Industry Recycling Coalition, and the Nickel Development Institute (NiDI) all opposed the release of any decontaminated scrap into the marketplace. On December 21, 1999, NiDI presented a 15-page brief to the U.S. Nuclear Regulatory Commission (NRC) opposing the entry of any "low-level" radioactive nickel scrap into the commercial recycling stream (Nickel Development Institute, 1999a, b). On January 6, 2000, the Specialty Steel Industry of North America issued a similar statement opposing the DOE plan and reaffirming its "zero tolerance" policy toward potentially radioactive scrap metals (Nuclear News, 2000). Because of the strong opposition from the metals industry, the U.S. Secretary of Energy decided on January 12 to prohibit the release of decontaminated nickel scrap into the marketplace until national treatment standards could be developed (U.S. Department of Energy, 2000; Washington Post, 2000). The prohibition also applied to at least 10,000 t of nickel-bearing scrap stored at other DOE facilities (Nuclear News, 2000; U.S. Department of Energy, 2000).

The NRC has begun developing national treatment standards for all volumetrically contaminated materials, including the DOE nickel. Public hearings were held to give concerned citizens an opportunity to participate in developing the new standards.

National Toxicology Program.—The U.S. Department of Health and Human Services was evaluating evidence on the toxicity and carcinogenicity of nickel metal and its alloys. The scientific review was being carried out as part of the National Toxicology Program (NTP). The NTP is funded by the National Institute of Environmental Health Sciences under various Congressional mandates.

From December 13 to 15, 2000, the NTP Board of Scientific Counselors met in Washington, DC, to review the evidence on nickel and seven other nominations. The Board was composed of scientists from the public and private sectors and had been providing primary scientific oversight to the NTP Executive Committee. J&L Specialty Steel Inc., the Specialty Steel Industry of North America, Inco US Inc., the Nickel Producers Environmental Research Association (NiPERA), and the U.S. Food and Drug Administration all made presentations to the Board. The NiPERA representative pointed out that two alloys with the same nickel content can have completely different nickel release rates and, thus, different levels of carcinogenicity. After the presentations, the Board voted to include metallic nickel in the 10th Edition of the Report on Carcinogens. The Board recommended that metallic nickel be treated in the future as a "reasonably anticipated carcinogen." However, the Board voted not to list nickel alloys without more conclusive research and test data.

Environmental Programs.—The Portable Rechargeable Battery Association, a nonprofit trade association comprised of about 90 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, continued to expand its nationwide battery collection and recycling system. The nonprofit, public service recycling program was being administered by Rechargeable Battery Recycling Corp. (RBRC) of Atlanta, GA. The RBRC was supported by more than 285 manufacturer/marketer licensees and a network of 26,000 collection locations across the United States and Canada. The program was made possible by the passage of "The Mercury-Containing and Rechargeable Battery Management Act" (Public Law 104-142) in 1996. The bulk of the spent nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries was being shipped to a pyrometallurgical reclamation facility at Ellwood City, PA. The facility was operated by the International Metals Reclamation Co. Inc. (Inmetco), a subsidiary of Inco Ltd.

New Coinage.—The European Union (EU) and the United States were in the process of issuing new coinage. The two Governments, however, have taken different positions with respect to nickel. The EU has limited nickel in its new coinage to minimize the potential risk of hypersensitive members of the public contracting nickel dermatitis. The U.S. Mint continued to use the cupronickel cladding previously in circulation and apparently has received few complaints about the cladding causing nickel dermatitis.

Commemorative Quarters.—The U.S. Mint produced 6.47 billion quarters (25-cent coins) in 2000, up from 4.43 billion in 1999. The cupronickel-cladded coins were part of the popular 50 State Quarters™ Program launched in December 1998. Between 40 and 60 billion quarters will have been minted when the program ends in 2008. Each State was being honored with its own coin showing George Washington on the obverse (front) and a unique statehood design on the reverse. The five States honored in 2000 were Massachusetts, Maryland, South Carolina, New Hampshire, and Virginia (in order of minting). Since each coin weighs 5.67 grams and contains 8.33% Ni, the total quantity of nickel ending up in the five commemoratives released in 2000 was about 3,060 t.

The U.S. Mint also began releasing the new Golden Dollar coin in March. The dollar coin has an overall composition of 88.5% copper (Cu), 6.0% zinc, 3.5% manganese, and 2.0% Ni.

Euro Coinage.—The European Monetary Union (EMU) was scheduled to have its new euro coinage in circulation by January 1, 2002. After July 1, 2002, coins of the individual member States would no longer be legal tender and were to be scrapped. Because of health considerations, the EMU was using a nickel-free alloy called Nordic Gold for the 10-, 20-, and 50-eurocent pieces and copper-covered steel for the 1-, 2-, and 5-eurocent pieces (Outokumpu Oyj, 1998b). Only the 1- and 2-euro coins contained nickel (Outokumpu Oyj, 1998a). EuroCoin AG, a group of companies within Vereinigte Deutsche Nickel-Werke AG, was one of several contractors making blanks for the German mint. Since 1998, the participating mints have built up huge stockpiles of the new coins at undisclosed locations throughout the EU in anticipation of the 2002 exchange period. The old national coins—many of which contain significant nickel—will be defaced and stockpiled until they can be melted down by contractors into remelt alloys.

National Defense Stockpile.—On June 10, 1999, the U.S. Government sold the last of the nickel in the National Defense Stockpile.

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Production

Primary Production.—The United States did not produce any primary nickel in 2000. The Glenbrook Nickel Co. was in the process of decommissioning its mining and smelting complex at Riddle, OR. All of the electric arc furnaces have been dismantled and scrapped. The calciner has been moved to another location and will not be used for ferronickel production. Glenbrook, a subsidiary of Teck Cominco Ltd., permanently closed the smelter in March 1998 after the world ferronickel price fell below $6,000 per metric ton ($2.72 per pound) of contained nickel. The recent startup of a greenfield ferronickel operation in Venezuela and the expansion of existing capacity in Colombia, Indonesia, and New Caledonia have discouraged potential ferronickel producers from building facilities elsewhere in the Western United States.

Secondary Production.—Inmetco continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel from wastes generated by the stainless steel industry. Because of subsequent improvements to the facility, Inmetco can accept a broad spectrum of other recyclable nickel- and/or chromium-bearing wastes, including filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries (Barozzi, 1997).

Inmetco is the only facility in North America that can thermally recover cadmium from NiCd batteries. The cadmium circuit employs a technology that the U.S. Environmental Protection Agency (EPA) has determined to be the best demonstrated available technology for cadmium reclamation. The RBRC program has been encouraging consumers to return their spent NiCd and NiMH batteries to commercial outlets where they are stockpiled and eventually shipped to Ellwood City. The small rechargeable cells are used in a variety of devices, including cellular telephones, transceivers, portable power tools and appliances, medical equipment, and emergency lighting systems. Inmetco also reclaims large industrial cells that are used by railroads, electric utilities, the military, and telecommunication companies for backup power. An estimated 1,600 t of NiCd batteries were collected in the United States and Canada in 2000. Although the tonnage of nickel-based batteries being recycled has increased dramatically since 1996, a significant number still end up in landfills. The RBRC is hoping that future improvements in its program will significantly reduce the tonnage being landfilled.

Byproduct Production.—Limited quantities of nickel were recovered at some copper and precious-metals refineries and at a few plants that reclaim spent catalysts.

The Stillwater Mining Co. has been mining platinum-group metals (PGM) and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The ore is associated with the 45-kilometer (km) long J-M Reef. Concentrates from the Stillwater Mine were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing approximately 60% palladium and platinum was being produced. In 2000, the refinery also produced a byproduct nickel-cobalt solution, which was trucked to Canada where the two metals were recovered. Other byproducts were copper, rhodium, selenium, silver, and tellurium (Stillwater Mining Co., 2001a, p. 18-21; b, p. 3-10).

Stillwater was in the process of expanding the Columbus smelter and has begun construction of a centralized concentrate sampling and drying facility. A second top blown rotary converter was scheduled to come on-stream in late 2001. The expansion was needed to accommodate concentrates from the new East Boulder Mine under development in the western half of the J-M Reef. Several improvements also were made to the refinery in 2000. Copper, selenium, and tellurium are now being recovered on-site by pressure leaching. After removal of the selenium and tellurium, the copper-rich solution is fed to an electrowinning circuit. A nickel sulfate crystallizer circuit, still in the final stage of construction at yearend, became operational in mid-2001. The new crystallizer circuit allows the company to ship its nickel sulfate byproduct as a solid rather than a liquid, minimizing environmental risks and reducing shipping costs.

The Nye mill processed a total of 686,000 t of ore in 2000, with a mill head grade of 20 grams per ton (g/t) of palladium plus platinum. All of the ore came from the Stillwater Mine at the eastern end of the reef. Development of the East Boulder Mine near Big Timber has been underway since mid-1998. The first of two tunnel boring machines intersected the J-M Reef on June 25, 2000. The second boring machine reached the reef on August 24. The East Boulder Mine was scheduled to begin production in 2002 (Stillwater Mining Co., 2001a, p. 2-17).

Spent catalysts are another U.S. source of byproduct nickel. In early 2000, CS Metals of Louisiana, LLC commissioned a spent catalyst reclamation facility on the Mississippi River at Convent, LA. The plant was designed to recover vanadium oxide and molybdenum oxide from spent catalysts used in oil refining and petrochemical operations. The facility also produces a nickel-cobalt byproduct. CS Metals is a joint venture of Strategic Minerals Corp. (Danbury, CT) and CRI International Inc. (Houston, TX), a wholly owned member of the Royal Dutch/Shell Group of companies. The fully permitted plant is in the Baton Rouge/New Orleans refining corridor and uses a patented hydrometallurgical process that produces no solid waste (Strategic Minerals Corp., 1999).

Gulf Chemical and Metallurgical Corp. of Freeport, TX, also processes spent catalysts. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts with or without vanadium present. The principal products are oxides of molybdenum and vanadium, fused alumina, and a crude nickel-cobalt alloy byproduct. The nickel-cobalt alloy is produced in an electric furnace and available for sale to nickel refineries. Several of the metals recovered from the spent catalysts are used to manufacture fresh hydrotreating catalyst.

Encycle/Texas, Inc. of Corpus Christi, TX, and U.S. Filter Recovery Services, Inc. of Roseville, MN, have been recovering limited amounts of nickel from electronic scrap and electroplating sludge. Encycle, a wholly owned subsidiary of ASARCO Inc., is now using an innovative electrowinning process to fully reclaim metals from wastes brought to the facility. U.S. Filter recently launched an EPA-approved pilot program that uses ion exchange resins to treat waste waters at electroplating operations.

Consumption

In 2000, demand for primary nickel in the Western World was estimated to have reached an alltime high of 1,029,000 t, surpassing the previous record of 1,004,000 t (revised) set in

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1999 (International Nickel Study Group, 2001b, p. 3-17). U.S. apparent consumption of primary nickel was 147,000 t, or about 14% of Western demand. U.S. industry consumed an additional 84,000 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels fell from 44% in 1999 to 39% in 2000. The drop was attributed to higher prices for primary nickel, the increased availability of scrap, and increased demand for superalloys and other nickel-base alloys. The estimated value of apparent primary consumption in the United States in 2000 was $1.27 billion. Even though consumption declined slightly due to increased prices for primary nickel, the $1.27 billion figure was 51% higher than that of 1999.

Stainless Steel and Low-Alloy Steels.—In 2000, the United States and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 33% of primary nickel demand in the United States and more than 60% of primary demand in the world. The percentage for the United States was lower because its stainless steel producers operated with higher scrap ratios than some of its foreign competitors.

Production of raw stainless steel in Western countries has doubled in the past 14 years, growing to 17.28 million metric tons (Mt) in 1999 from 7.92 Mt in 1985 (Inco Ltd., 2000f, p. 3-25). Utilization of stainless melt capacity in the Western World has climbed from an estimated 74% in 1996 to 87% in 2000. Because of the high utilization rate, additional melt capacity will have to be brought on-stream by 2005 to accommodate the projected growth in demand for stainless. Between 2002 and 2005, additional capacity is expected to start up in the EU, the Republic of Korea, Taiwan, and the United States. In the interim, reduced growth in demand in East Asia and other overseas markets since 1997 has encouraged foreign stainless steel producers to increase their exports to the United States. Total U.S. imports of stainless steel mill products have grown by 35% since 1996, but domestic production has risen by only 17%.

Production of raw stainless and heat-resisting steel in the United States totaled 2.19 Mt in 2000, almost the same tonnage as in 1999. The tonnage was the highest on record, even higher than that of 1974 when the EPA first required automobiles to have emission control systems. Nickel-bearing grades accounted for 1.24 Mt, or 56% of the total stainless production for 2000 (American Iron and Steel Institute, 2001b). Net shipments of all types of stainless totaled 1.93 Mt, an 11-year high (American Iron and Steel Institute, 2001a, p. 26-29). Shipments of sheets and strip increased 4% to 1.53 Mt, breaking the previous record of 1.47 Mt set in 1999. Shipments of plate, the next largest category, were 188,000 t, or 2% less than that of 1999. Although U.S. stainless steel production and net shipments were practically unchanged from 1999 levels, stainless steel imports increased 6% to 1.07 Mt.

North American Stainless, a subsidiary of Acerinox SA (Madrid, Spain), was building a melt shop at its steel rolling operations in Ghent, KY. The new melt shop was expected to be a major consumer of primary nickel and stainless steel scrap. The facility is designed to produce about 800,000 metric tons per year (t/yr) of hot metal and should be operational by yearend 2001.

Superalloys and Related Nickel-Base Alloys.—About 30% of the primary nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of nickel-base alloys was up from 1999 because of a strengthening of sales to aircraft manufacturers and manufacturers of turbines for land-based powerplants.

Demand for superalloys is partially reflected in the production backlog and new orders for jet aircraft. Turbine blades, discs, and other critical parts of jet engines are fabricated from superalloys. In 2000, the U.S. aerospace industry earned $9.4 billion on sales of $144 billion—the second highest profits on record (Napier, 2000). Total sales were 4.9% less than those of 1999, when profits peaked at $10.2 billion. The U.S. Government accounted for only 46% of domestic aerospace products and services compared with 70% a decade ago (Napier, 2000). Boeing Co. and its McDonnell Douglas Corp. subsidiary increased their backlog of orders for civil jet transports. A total of 585 net orders for large civil jet transports was received in 2000, compared with 346 in 1999 (Aerospace Industries Association of America, Inc., 2001). Between 1999 and 2000, actual shipments decreased, falling from 620 aircrafts to 485. On December 31, 2000, Boeing had a backlog of 1,612 aircrafts, up from 1,512 at yearend 1999.

Mergers, Acquisitions, and Closures.—The specialty steel industry of the United States continued to restructure in the face of growing imports of stainless steel. U.S. superalloy producers, which have close ties to some of the specialty steel producers, also restructured. The principal force driving the mergers and acquisitions has been the financial synergies created by the integration of similar specialty metals operations.

On November 29, 1999, the management of Allegheny Teledyne Inc. completed its reconfiguration of the company. Only operating units involved in the production and marketing of specialty materials were retained. After the consumer-oriented units were spun off, Allegheny Teledyne changed its name to Allegheny Technologies Inc. The retained units had combined sales of $2.46 billion in 2000, up from $2.30 billion in 1999. The aerospace, automotive, and electrical energy markets accounted for 17%, 13%, and 12%, respectively, of sales. Allegheny Technologies also supplied advanced materials, nickel-based alloys, titanium alloys, and specialty steels to the oil and gas industry for use in drill holes, drilling rigs, and refining plants (Allegheny Technologies Inc., 2001, p. 1-15).

In November 1999, Allegheny Ludlum Corp., the company's specialty steel unit, offered Bethlehem Steel Corp. $20.5 million in cash for its closed stainless steel sheet and strip mill at Washington, PA. Bethlehem accepted and the sale was completed on December 22, 1999. Allegheny Ludlum announced that it would restart the plant's Sendzimir mills together with its annealing and pickling lines (Allegheny Technologies Inc., 1999a, b).

In June 2000, Slater Steel Inc. of Mississauga, Ontario, purchased two Canadian specialty steel operations from Atlas Steels Inc. for C$122 million in cash and the assumption of long-term debt of about C$16 million. The acquisition of Atlas Specialty Steels and Atlas Stainless Steels was finalized on August 1. Shortly afterward, Slater launched a long-term program designed to integrate its U.S. and Canadian specialty steel operations with those of the two former Atlas subsidiaries (Slater Steel Inc., 2000a, b, c). The newly consolidated company now owns and operates the following five minimills in North America:

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(1) the Fort Wayne Specialty Alloys division in Indiana—a leading producer of stainless steel bar products and the only producer of stainless steel angle in North America;
(2) the Hamilton Specialty Bar division at Hamilton, Ontario—a producer of alloy steel bar and grinding balls which Slater owned prior to the acquisition;
(3) the Atlas Specialty Steels complex at Welland, Ontario;
(4) Atlas Stainless Steels—a stainless steel strip, sheet, and plate operation at Tracy, Quebec; and
(5) Sorel Forge Inc.—a producer of carbon, alloy and stainless steel forgings at Sorel, Quebec, which Slater owned prior to the acquisition.

On August 7, Slater announced that it would close its melt shop at Fort Wayne, IN, in early 2001. The closure would directly affect about 90 employees. Slater was planning to consolidate melting operations at its newly acquired facilities in Welland, Ontario. The Welland melt shop was newer and had significantly more capacity than the Fort Wayne shop. Modernizing the Fort Wayne melt shop would have cost an estimated $30 million (Slater Steel Inc., 2000c). Slater's management believed that the consolidation would make the company more competitive and help ward off growing imports of stainless steel into North America. (See Foreign Trade.)

Advanced Castings and Forgings Industry.—Nickel is used in a variety of brass, stainless steel, and superalloy castings. Nickel also is added to gray-iron castings to toughen the iron, promote graphitization, and improve machinability. The U.S. castings industry shipped an estimated 1.3 Mt of steel castings and 2.5 Mt of nonferrous castings in 1999. Iron castings were about 9.4 Mt. The U.S. foundry industry has consolidated dramatically over the past 40 years. The number of foundries in North America has declined from approximately 6,000 in the 1960s to 3,000 in 2000. Since 1985, Caterpillar Inc., Deere and Co., Gardner Denver Inc., General Electric Co., General Motors Corp. (GM), Siemens Westinghouse Power Corp., and several other major manufacturers of machinery or vehicles have closed one or more of their in-house foundries. In 1999, there were only 400 steel foundries and 700 iron foundries in the United States. At the same time, capacity utilization has increased from 45% to 85%. Cast components are becoming increasingly complex, especially those going to the aerospace and power generation sectors (Atchison Casting Corp., 2000, p. 6-8; Atchison Casting Corp., 2001 inside front cover and p. 1-18).

On June 20, Alcoa Inc. completed its acquisition of Howmet International Inc. Howmet is the largest manufacturer of investment cast turbine engine components in the world and a significant consumer of nickel. Many of the advanced superalloy castings produced by the company are incorporated into jet aircraft engines or industrial gas turbines (Alcoa, 2000c). Many of the nickel-base and other high-temperature alloys used as starting material are produced at the company's metallurgical complex in Dover, NJ. Alloy production from the Dover facility supports several casting plants in the United States, Europe, and Japan. Howmet's corporate headquarters are in Greenwich, CT. The purchase strengthened Alcoa's ties to the U.S. automotive industry and was expected to bring Alcoa closer to Airbus Industrie S.A.S. because of Howmet's business in both new-generation and after-market jet engine components. The purchase also provided Alcoa with an entry into the fast-growing industrial gas turbine market.

On April 18, Alcoa made a cash tender offer of $20 per share to Howmet shareholders after direct negotiations with Howmet's Board of Directors stalled. At that time, about 15.4 million shares of Howmet common stock were outstanding. On June 2, Alcoa raised its offer to $21 per share and ended up paying about $324 million for the stock (Alcoa Inc., 2000a). The Howmet acquisition came less than a month after Alcoa acquired Howmet's parent—Cordant Technologies, Inc. of Salt Lake City, UT. The acquisition of Cordant was completed on May 25 after Alcoa received clearance from antitrust authorities in the EU and the United States (Alcoa Inc., 2000b). Cordant owned 84.7% of Howmet's outstanding shares prior to the May transaction (Alcoa Inc. and Cordant Technologies, Inc., 2000).

On January 12, 2000, Precision Castparts Corp. (PCC) of Portland, OR, completed its acquisition of the Wyman-Gordon Co. The acquisition was made through a cash tender valued at $731 million (Precision Castparts Corp., 2000, p. 1-5, 25-28). The acquisition, which ended up costing $784 million, broadened PCC's capabilities in the aerospace industry and also gave the Oregon-based company a niche in the aluminum castings business. Wyman-Gordon is a leading producer of forgings for the aerospace, industrial gas turbine (IGT), and energy markets. PCC makes superalloy investment castings for the aerospace, power generation, and general industrial sectors. Many of these castings contain significant nickel. PCC also makes investment castings for automotive and medical applications. The acquisition offered considerable synergies, cost reduction, and manufacturing improvements. PCC now has a much stronger presence in the booming IGT market. For the time being, Wyman-Gordon will operate as a separate Precision Castparts business while maintaining its own forging business identity.

During the year, PCC also acquired Drop Dies & Forgings Co. of Cleveland, OH, and UEF Aerospace of Lincoln, England. Drop Dies & Forgings specializes in the production of high-quality forgings from difficult-to-forge metals, including aluminum, titanium, and high-temperature nickel superalloys. UEF Aerospace, a unit of the British automotive specialist United Engineering Forgings, Ltd., was made a division of Wyman-Gordon. UEF Aerospace (renamed Wyman-Gordon Lincoln Ltd.) produces forged engine discs, engine shafts, and airframe and landing gear components, primarily for British jet engine maker Rolls-Royce plc (Precision Castparts Corp., 2001, p. 1-3).

Nickel-Based Batteries.—U.S. demand for nickel in rechargeable batteries may now exceed U.S. demand for several other important end uses, such as copper-nickel alloys and coinage.

Battery Manufacturing.—Texaco Ovonic Battery Systems LLC (formerly GM Ovonic LLC) manufactures NiMH batteries for electric, hybrid electric, and fuel cell electric vehicles. The main plant is at Kettering, OH. Some key battery components, though, are produced in development facilities operated in Troy, MI, by Ovonic Battery, Inc.—one of Texaco Ovonic's parents. Ovonic Battery and GM formed the joint venture in 1994 to manufacture electric vehicle (EV) batteries using proprietary NiMH technology developed by Ovonic Battery. Prior to 2000, GM had a 60% interest in the joint venture; Ovonic Battery, 40%.

On May 1, 2000, Texaco Inc. purchased a 20% equity interest in Energy Conversion Devices, Inc. (ECD) of Troy, MI, for $67.4 million. ECD, in turn, has a 91.4% interest in Ovonic Battery. ECD is a leading developer of advanced energy

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technologies and is perhaps best known for its patents on the NiMH battery (Texaco Inc. and Energy Conversion Devices, Inc.; 2000 Energy Conversion Devices, Inc., 2001, p. 7-18). In early October, ECD, GM, and Texaco restructured GM Ovonic. Texaco took over GM's interests in the Kettering operation and is now an equal partner with Ovonic Battery. GM has since designated Texaco Ovonic as a preferred supplier for its NiMH battery requirements and is collaborating on a development program with the battery manufacturer. The sale of GM's interests to Texaco was completed on July17, 2001.

Texaco formed two other joint ventures with ECD in 2000 that were aimed at further developing and eventually commercializing fuel cells for automobile propulsion. (See Current Research and Technology.)

Electric and Hybrid Electric Vehicles.—Although EVs were being commercially manufactured in the EU, Japan, and the United States, production and sales were still limited. Fewer than 6% of the 2002-model automobiles and trucks arriving at U.S. dealerships were able to get more than 7.8 liters per 100 kilometers (L/100km) or about 30 miles per gallon (mpg). Of the 491 passenger car models evaluated in combined city and highway driving by the EPA in 2001, the average fuel economy was only 9.84 L/100km or 23.9 mpg. The best achievers were two hybrid gas- and electric-powered vehicles. The hybrids—the two-seat Honda Insight coupe and the five-seat Toyota Prius sedan—were rated at 3.7 L/100km (or 64 mpg) and 4.9 L/100km (or 48 mpg), respectively (Heilprin, 2001).

At yearend 2000, at least six EV models equipped with NiMH batteries were being sold or leased in the United States. A total of 1,270 battery electric light-duty passenger vehicles and trucks were reported leased or sold in 1999. A significant number of the 1,270 vehicles, especially trucks, used lead-acid batteries as a cost savings measure. The new Generation I NiMH battery made by Texaco Ovonic can store twice the energy of a conventional lead-acid battery for the same weight and volume. At yearend 2000, more than 4,000 EVs were on U.S. highways. Sales of hybrid electric vehicles (HEVs) were growing at a much faster rate—4,402 Honda Insight coupes and 8,052 Toyota Prius sedans were sold or leased between October 1999 and March 2001 (Electric Vehicle Association of the Americas, 2001).

On December 22, 1999, the United States Postal Service ordered 500 electric mail delivery vehicles from the Ford Motor Co. and its partner, Baker Electromotive, Inc., of Rome, NY. The postal service had an option to order 5,500 additional vehicles. The design of the delivery vehicle was based largely on Ford's Ranger EV. Production began in the fall of 2000 and was to continue through 2001 at the rate of 45 vehicles per month. The purchase will increase the Federal electric vehicle fleet by more than 400% (Ford Motor Co. and Baker Electromotive, 1999).

Stocks

On December 31, 2000, U.S. consumer stocks of primary nickel (cathode, pellets, briquets, powder, etc.) totaled 6,490 t—34% greater than the 4,850 t (revised) at yearend 1999. Stocks in London Metal Exchange (LME) warehouses worldwide, in contrast, plummeted 79% during 2000 to 9,678 t. LME stocks at yearend 1999 and 1998 were 46,962 t and 65,964 t, respectively. Data collected by the International Nickel Study Group indicated that, at yearend 2000, world nickel producers (excluding those in Austria, China, the former Yugoslavia, and the Ural area of Russia) had approximately 87,500 t of nickel in primary products in stock (International Nickel Study Group, 2001b, p. 10-11).

Prices

The monthly average cash price for 99.8% pure metal on the LME peaked in March at $10,280 per metric ton ($4.663 per pound) and then gradually declined throughout the rest of the year. (See figure 1.) By yearend, the monthly average price had fallen to $7,314 per ton ($3.318 per pound). The cash prices for January and February 2001 were even lower—$6,995 per ton ($3.173 per pound) and $6,524 per ton ($2.959 per pound), respectively. The weakening of prices was attributed primarily to the economic slowdown in the United States and parts of East Asia. The end of strikes at Canadian nickel mines, the ramping up of three new pressure-acid-leach complexes in Australia, and the startup of the Loma de Niquel ferronickel operation in Venezuela also helped to lower prices in the second half of 2000 by firming up Western World supplies. The supply increase was partially offset by a strengthening of demand for stainless steel in East Asia, which kept nickel prices from collapsing in the fourth quarter. Japanese production of austenitic stainless steel increased from 1.84 Mt gross weight in 1999 to 2.07 Mt in 2000, an increase of 12% (International Nickel Study Group, 2001b, p. 18). The East Asian recovery also led to increases in stainless steel production in the Republic of Korea and Taiwan (World Bureau of Metal Statistics, 2000, p. 8).

In 2000, the last weekly price (for the 4 days ending December 29) was $7,158 per ton ($3.247 per pound). The average annual price was $8,638 per ton ($3.918 per pound). The annual price was 44% higher than the 1999 average of $6,011 per ton ($2.727 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 56% in 2000—significantly less than the 63% for 1999 because of increased scrap usage. Imports accounted for 100% of primary supply. The United States imported 156,000 t of primary nickel in 2000, 12% more than the 139,000 t for 1999. Class I materials accounted for 86% of total primary imports received. Canada, as usual, supplied most of the primary imports. The second largest source was Russia, recapturing the position from Norway. RAO Norilsk Nickel has become an important source of nickel metal for the United States since the dissolution of the Soviet Union. Almost all of the Norwegian nickel was produced from foreign matte processed at Falconbridge Ltd.'s refinery in Kristiansand. Australia was in fourth place, with shipments from Murrin Murrin and the two other new pressure-acid leach plants near Kalgoorlie entering the United States for the first time. (See Australia.)

Prices for nickel-bearing scrap tracked those for primary nickel, decreasing almost continuously during the second half of 2000 because of the deteriorating economic outlook in the EU, the United States, and parts of East Asia. Increased exports of Russian scrap added to the downward pressure on primary and secondary prices. Most of the Russian scrap was consumed in

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the EU and did not enter the U.S. market. The EU imported 344,000 t (gross weight) of stainless steel scrap from Russia in 2000, the second highest tonnage in the past 5 years and 36% more than the 253,000 t in 1999 (International Nickel Study Group, 2001b, p. 64-65). U.S. exports of stainless steel scrap to the EU totaled 55,300 t (gross weight), up 59% from 1999 levels.

U.S. producers of specialty steels concerned about the country's continuing high level of specialty steel imports filed additional antidumping and countervailing duty petitions with the U.S. Department of Commerce and the U.S. International Trade Commission (ITC). In 2000, specialty steel imports reached a record 811,000 t (gross weight). Stainless steel accounted for 628,000 t, or 77% of the 811,000 t total. Electrical steel constituted 14%, and tool steel, 9% (Specialty Steel Industry of North America, 2001). Imports had slackened slightly in 1999 to 757,000 t because of the ongoing trade investigations, but began rising again in the first half of 2000, outpacing growth in U.S. consumption (Specialty Steel Industry of North America, 2000). Japan, the Republic of Korea, and Taiwan were cited in several of the U.S. producers' petitions. In 2000, total imports of all stainless steel long products (bar, rod and wire) captured 52% of the U.S. market.

On August 18, 2000, Slater Steels Corp. (the U.S. subsidiary of Slater) and the United Steelworkers of America filed an antidumping petition with the U.S. Government. The petition alleged that Japanese, South Korean, and Spanish producers were selling stainless steel angle in the United States at less than fair value. Stainless steel angle (a length of steel with a cross section resembling the letter L) is used to reinforce the interiors of stainless steel tanks commonly found in the food, dairy, and chemical processing industries. On September 28, the ITC determined preliminarily in a 6-0 vote that unfair trade practices had indeed injured domestic stainless steel producers. The stainless steel angle case was subsequently referred to the U.S. Department of Commerce for determination of antidumping margins (Slater Steels Corp.., 2000a, b).

World Review

The world's largest nickel producer was Norilsk Nickel, followed by Inco. Other major producers were Billiton plc of the United Kingdom, the Eramet Group of France, Falconbridge Ltd. of Canada, and WMC Ltd. of Australia. The six companies accounted for about 66% of world primary production in 2000. More than 30 medium to small companies supplied the remaining 34%. The nickel industry has become highly competitive as a result of recent corporate alliances and new developments in extractive metallurgy.

In December 2000, Anglo American plc commissioned its mining and smelting complex in Venezuela at Loma de Niquel. The mining giant increased or retained its holdings in several other medium-sized nickel producers. At yearend 2000, Anglo American had interests in the following six producers: Anaconda Nickel Ltd. of Australia (26%), BCL Ltd. of Botswana (23%), Bindura Nickel Corp. Ltd. of Zimbabwe (53.11%), Codemin S.A. of Brazil (90%), Minera Loma de Niquel, C.A. of Venezuela (85.5%), and Tati Nickel Mining Co. (Pty.) Ltd. of Botswana (43.35%). Anglo American also was involved in the Barro Alto Project (Brazil) and the Kabanga Project (Tanzania).

OM Group Inc. (OMG) of Cleveland, OH, has taken a number of steps since 1998 to transform the chemical company into a fully integrated nickel producer. OMG already had chemical production operations in the Congo, France, Germany, Malaysia, Thailand, and the United States before these actions were taken. In April 2000, OMG bought the nickel refinery at Harjavalta, Finland, from Outokumpu Oyj (Juusela, 2000). (See European Union—Finland.) OMG also formed a partnership with Weda Bay Minerals Inc. to evaluate the Halmahera laterite deposits in Indonesia. (See Indonesia.)

Global competition among stainless steel producers intensified in 2000. The increased competition and associated antidumping actions led to at least one key merger. On January 22, 2001, Avesta Sheffield AB and Outokumpu Steel Oyj merged their stainless steel manufacturing operations. The new consolidated company, AvestaPolarit Oyj Abp, became the world's second largest producer of stainless steel slabs. AvestaPolarit now has about 8,900 employees and was expected to have net sales of more than EUR 3.5 billion (about $3.2 billion) in 2001. Key production plants are located in Finland, Sweden, the United Kingdom, and the United States. The company's melt shop facilities in the four countries have a combined stainless steel slab capacity of about 1.7 million metric tons per year (Mt/yr) (Avesta Sheffield AB, 2001; Outokumpu Oyj, 2001; Outokumpu Oyj and Avesta Sheffield AB, 2000).

Avesta Sheffield and Outokumpu announced their intention to merge in September 2000, but first had to obtain approval from antitrust authorities in the European Commission and five foreign governments, including the United States (Avesta Sheffield AB, 2000). The new company is incorporated in Finland and has its head office in Stockholm. The merger had the full support of the Finnish State, which owned 40% of Outokumpu Oyj at the time. Exchanging of shares of Avesta Sheffield for shares of Outokumpu Steel began on December 21, 2000, and continued until February 2, 2001. Outokumpu Steel was renamed AvestaPolarit during the exchange period. The two largest shareholders in AvestaPolarit were Outokumpu Oyj (55.3% equity) and Corus Group plc (23.2%). Outokumpu Oyj agreed to reduce its holdings to 40% within 3 years so that AvestaPolarit's stock would be more liquid.

Outokumpu Steel's Kemi-Tornio complex is the only fully integrated stainless steel production operation in the world, starting with chromite ore and ending with finished stainless steel products. The new company was expecting to spend more than EUR 680 million (about $615 million) on expansion of its Tornio operation. Most of the money was being used to construct a new melt shop and expand rolling capacity (Outokumpu Oyj and Avesta Sheffield AB, 2000; AvestaPolarit Oyj Abp, 2001). The merger allowed Outokumpu Oyj, the parent of Outokumpu Steel, to focus on developing its remaining nonferrous businesses—copper and zinc.

Australia.—Australia is now the third largest nickel producing country in the world and is beginning to rival Canada. Most of the nickel properties under development are in Western Australia. By 2002, nickel production capacity of Western Australia is projected to reach 200,000 t/yr. WMC was still the largest nickel producer in the State, recovering 107,458 t of nickel in sulfide concentrate in calendar year 2000, up from 88,275 t in 1999 (WMC Ltd., 2001b).

Australian Sulfide Operations.—In early 2000, WMC increased production at its operations in Western Australia because of strengthening nickel prices. All three mining

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operations—Kambalda, Leinster, and Mount Keith—produced more in 2000 than in 1999. The Kambalda Mines showed the biggest gain, with output of concentrate increasing to 19,202 t of contained nickel in 2000 from 11,114 t. Production at the huge Mount Keith Mine northwest of Leinster resumed its upward trend, rising to 47,532 t from 41,208 t. Production at the Leinster Mines increased to 40,724 t from 35,953 t (WMC Ltd., 2001b). WMC's smelter at Kalgoorlie produced 103,000 t of Ni in matte, up from 79,668 t in 1999. During the year, WMC acquired the Yakabindie deposit, 25 km south of Mount Keith. The Yakabindie deposit contains an estimated 292 Mt of resources averaging 0.52% Ni (WMC Limited, 2001a, p. 16-17).

Australian Laterite Projects.—Pressure acid leach (PAL) production capacity continued to grow in Western Australia at a rapid rate. Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since mid-1998—Bulong, Cawse, and Murrin Murrin (Mining Journal, 1999b). Together, the three initially should eventually add about 60,000 t/yr of nickel to world production capacity. By May 2000, however, only Cawse had approached design capacity. The other two continued to experience ramp-up problems.

Murrin Murrin.—Anaconda Nickel Ltd. began producing nickel metal at its new Murrin Murrin refinery in May 1999 (Anaconda Nickel Ltd., 1999d). The metal reportedly had a chemical purity of greater than 99.80% Ni and was being marketed as briquets (Hagopian, 1999). Briquets produced in the fourth quarter of 2000 reportedly averaged 99.93% Ni, 0.026% cobalt (Co), and 0.002% Cu, fully meeting LME specifications (Anaconda Nickel Ltd., 2001).

The development plan originally called for production to be gradually increased during the second half of 1999 to the full Stage I design capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt (Anaconda Nickel Ltd., 1999e). Nickel production for 1999 was supposed to have been about 16,000 t (Platt's Metals Week, 1999a, b) but startup problems resulted in an actual output of only 1,000 t. In July 1999, Anaconda began a 100-day campaign to rectify several technical problems that had constrained production. Some of the problems were attributed to design flaws in the flash vessels of the plant's four autoclave systems. The flash vessels have since been converted from bottom entry to top entry. Stainless steel piping in some of the autoclave circuits was unable to withstand the corrosiveness of the acidic solutions and had to be replaced by titanium alloy pipe.

The Murrin Murrin refinery produced about 4,100 t of nickel in the fourth quarter of 2000. The complex is now scheduled to reach the original target of 45,000 t/yr of nickel in the first half of 2002. Anaconda was already preparing to launch Stage II and expand the capacity of Murrin Murrin to 106,000 t/yr of nickel and 7,600 t/yr of cobalt. Stage II would use a process developed in-house instead of the original Sherritt process (Anaconda Nickel Ltd., 2001). The expansion could make Murrin Murrin the largest nickel mine in Australia, surpassing Mount Keith. According to Anaconda officials, the resources of the Murrin Murrin project (including the Abednego property) now total more than 355 Mt of ore grading 0.99% Ni and 0.07% Co.

Mount Margaret Project.—Anaconda also was preparing to develop its Mount Margaret property, 100 km northwest of Murrin Murrin. Test work on the Marshall Pool and Lawlers ore bodies indicates a resource of at least 170 Mt grading 0.78% Ni and 0.045% Co (Anaconda Nickel Ltd., 1999f). Total resources in the Mount Margaret region reportedly exceed 585 Mt and average 0.67% Ni. Drilling was underway to better delineate the resources at Mount Margaret and a feasibility study was in progress.

The proposed centralized Mount Margaret nickel refinery would have an initial design capacity of 63,600 t/yr of nickel. The development of the Murchison properties northeast of Meekatharra would allow the Mount Margaret refinery to be expanded to 130,000 t/yr. The refinery would be fed by two modular PAL plants—one at Marshall Pool and the other at Murchison.

Bulong and Cawse.—Like Murrin Murrin, Bulong and Cawse experienced startup problems associated with the new PAL technology but eventually overcame the bulk of the problems and are now in production. The two also were using solvent extraction technology to separate the cobalt from the nickel. All three, however, had somewhat different circuits.

In March 1999, Preston Resources Ltd. began continuously producing nickel metal at Bulong (Mining Journal, 1999c). Preston was also stockpiling cobalt sulfides (Mining Journal, 1999a), although the Bulong cobalt refinery was still in the final stages of commissioning. The Bulong complex was originally designed to produce 9,000 t/yr of nickel and 700 t/yr of cobalt. In October 1999, Anaconda and Preston agreed to jointly expand Bulong's production capacity and were considering raising the nickel output of the complex to 40,000 t/yr. Anglo American—Anaconda's partner—was reportedly backing Anaconda's involvement. Anaconda agreed to manage Bulong for Preston and review existing work. Anaconda can earn up to a 60% interest in Bulong. Preston's largest shareholder, Resolute Ltd., reportedly agreed to support the joint venture under certain conditions. The expansion feasibility study was scheduled to be completed by August 2001.

The Cawse complex is in the Eastern Goldfields region, 60 km northwest of Kalgoorlie. The complex produced its first cobalt sulfide concentrate, assaying 40% Co, on December 25, 1998, and the first nickel cathode was made on January 20, 1999 (Western Australian Department of Resources Development, 1999). The complex is owned and operated by Centaur Mining and Exploration Ltd. When fully operational, Cawse is expected to produce 8,700 t/yr of nickel and 1,300 t/yr of cobalt.

In November 1999, Anaconda formed a strategic alliance with Centaur Mining to expand the Cawse operation (Anaconda Nickel Ltd., 1999a). Anaconda and Centaur proposed raising the capacity of Cawse to more than 50,000 t/yr. The two companies were expecting to complete an expansion feasibility study by mid-2001. Anaconda was to be responsible for the financing, construction, commissioning, and operation of the expanded plant. Anaconda could earn as much as a 60% interest in Cawse.

Marlborough.—Preston also was preparing to develop the Marlborough laterite deposit on the central Queensland coast, about 75 km northwest of Rockhampton. Marlborough Nickel Pty. Ltd., the project manager, was in the process of securing the permits required for development and construction. Marlborough Nickel is a wholly owned subsidiary of Preston. The proposed hydrometallurgical complex would produce 25,000 t/yr of nickel metal and 2,000 t/yr of cobalt metal. Sufficient resources have been identified to permit the plant to

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operate for at least 22 years and possibly 100 years. According to company officials, Marlborough has about 210 Mt of resources grading 1.02% Ni and 0.06% Co (Preston Resources Ltd., 1999).

Ravensthorpe Project.—Comet Resources Ltd. (formerly Comet Resources NL) and BHP Billiton plc were preparing to develop the Ravensthorpe nickel property, 150 km from the southern port of Esperance. Comet's latest plan called for the complex to have a design capacity of 35,000 t/yr of nickel metal and 1,400 t/yr of cobalt sulfide (Comet Resources NL, 1999; Comet Resources Ltd., 2000). Construction of the Halleys cut—the proposed initial open pit on Bandalup Hill—was scheduled to begin in early 2001. The first of three pits would have a projected life of 10 to 15 years. Like Marlborough, the ore would be beneficiated before being fed into an autoclave. The beneficiated ore would have a nickel content of 2.0%. The PAL plant would adjoin the ore beneficiation plant.

In November 1999, QNI Pty. Ltd., the Queensland subsidiary of BHP Billiton, paid Comet $22 million for a 40% interest in the project. The proposed Ravensthorpe PAL plant would ship an intermediate nickel and cobalt concentrate to QNI's existing Yabulu plant near Townsville, Queensland (Mining Journal, 1999d). In September 2000, QNI acquired an additional 10% from another venture partner. On March 9, 2001, QNI agreed to purchase Comet's remaining interest in Ravensthorpe for $14.3 million plus the cancellation of its 19.9% interest in Comet (Billiton plc, 2001a).

Processing of Intermediates and Refining.—QNI produced 25,208 t of nickel metal at its Yabulu refinery during fiscal year 1999-2000 (Billiton plc, 2000). Laterite feed for the refinery was being supplied by PT Aneka Tambang (Persero) Tbk. (AnTam) in Indonesia, Hinatuan Mining Corp. in the Philippines, and four mining companies in New Caledonia.

Canada.—Key events of 2000 are summarized in the nickel chapter of the Canadian Minerals Yearbook (McCutcheon, 2001).

Labrador.—Inco Ltd. and its subsidiary Voisey's Bay Nickel Co. Ltd. (VBNCL) remained committed to developing the huge nickel-copper-cobalt deposit at Voisey's Bay. An impasse between Inco and the Provincial Government of Newfoundland and Labrador over the scope of the project continued to delay development (Inco Ltd., 1999). On January 11, 2000, Inco and the Provincial Government mutually agreed to suspend negotiations on the Voisey's Bay Project. Spokespersons for Inco and the Provincial Government were not willing to predict when negotiations might resume.

Inco has decided to recover the nickel using a new hydrometallurgical process developed in-house instead of using flash smelting technology as originally planned. On November 14, 1999, Inco delivered a new development proposal for Voisey's Bay to the Provincial Government (Whyte, 1999). In the proposal, Inco offered to build a hydrometallurgical pilot plant in the Province but did not want to commit to building a full-scale facility until the new process was determined to be technically and economically feasible. The proposed pilot plant and associated research and development program would have cost about $125 million (Inco Ltd., 2000f). Inco also would have spent about $65 million on underground exploration at the mine site.

Despite the impasse, Inco was permitted to push ahead with its surface exploration program. According to Inco, the Voisey's Bay deposit has 32 Mt of proven reserves averaging 2.83% Ni and 1.68% Cu. All of these reserves reportedly can be recovered by open pit mining. In addition to these reserves, geologists have calculated that there are 95 Mt of indicated resources averaging 1.28% Ni and 0.60% Cu plus 14 Mt of inferred resources averaging 0.98% Ni and 0.66% Cu (Inco Ltd., 2001, p. 26-27). The bulk of these resources would have to be recovered using underground mining techniques. A minihydrometallurgical pilot-plant program was scheduled to begin in 2001 at the company's Sheridan Park research center.

Inco was working with the Labrador Inuit Association to establish baseline metal concentrations in meadows and other sensitive areas near the proposed mine site. The baseline environmental data will be used to ensure that metal concentrations do not rise when commercial mining begins.

On December 14, Inco redeemed the Class VBN shares that were issued when Diamond Fields Resources Inc. and the Voisey's Bay deposit were acquired in 1996. Each VBN share was exchanged for C$7.50 in cash and a fraction, 0.45, of an Inco common share purchase warrant. The warrant can be used to purchase one Inco common share for C$30.00 on or before August 21, 2006.

South Voisey's Bay, Labrador.—Donner Minerals Ltd. and its partners had planned to spend C$2.75 million exploring their claims in the South Voisey's Bay (SVB) project area during the 1999 field season. However, on July 6, 1999, Donner announced that the company had been unable to reach an agreement with the Innu Nation, which was still conducting land claims negotiations with the Federal and Provincial Governments. Donner was unwilling to risk a confrontation at its SVB exploration camp and decided to cancel its 1999 exploration program (Donner Minerals Ltd., 1999). Donner kept the exploration program on hold throughout 2000 while it negotiated with the Innu Nation.

Ontario.—The Sudbury region of Ontario, northwest of Lake Nipissing, has been the principal nickel-producing district in Canada since 1883. Inco operates a smelting complex at Copper Cliff, on the western edge of the City of Sudbury. Falconbridge Ltd. has a somewhat smaller smelter near the town of Falconbridge. Concentrates for the two smelters come from a number of underground mines ringing the perimeter of the Sudbury Basin. Ore production at Falconbridge's four Sudbury mines totaled only 1.79 Mt and was down 35% from 2.75 Mt in 1999 because of a prolonged labor strike and the impact of a rockburst in the Fraser Mine. The ore averaged 1.54% Ni and 1.37% Cu (Falconbridge Ltd., 2001, p. 18-19).

Falconbridge and Inco have continued to find additional resources along the basin rim. Inco and two major producers of PGM recently accelerated their exploration efforts in the region. Higher nickel prices, improved PGM fundamentals, and two recent discoveries of nickel-copper sulfides on the southern perimeter of the Sudbury Basin all contributed to the expansion of exploration activities.

Kelly Lake and Totten Deposits.—Inco management was expected to decide in 2001 when the Kelly Lake deposit should be brought into production. The deposit is 2 km south of Copper Cliff and Highway 17 and reportedly is accessible from existing mine workings near Inco's Copper Cliff South Mine.

Inco geologists continued to evaluate a new area of mineralization in and around the Totten Mine, near Worthington on the Canadian Pacific Railway. The mineralization was discovered in late 1999. Subsequent drilling indicated that the

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Totten deposit has at least 8.4 Mt of resources averaging 1.42% Ni, 1.90% Cu, and 4.7 g/t of PGM (Inco Ltd., 2000d). If the necessary environmental permits can be obtained in 2001, production could begin as early as 2005.

The Kelly Lake and Totten deposits both have average nickel and PGM concentrations higher than those being mined by Inco's Ontario Division. The average ore grade for the Division currently is 1.41% Ni, 1.40% Cu, and 1.8 g/t of PGM. Because of the two new finds, Inco decided to spend $7.7 million in 2000 exploring several high potential targets in the region. This was Inco's highest annual exploration expenditure (in nominal dollars) in Ontario since the 1970s.

Other Nickel-PGM Targets.—Anglo American Platinum Corp. Ltd. of Johannesburg, South Africa, has teamed up with Pacific Northwest Capital Corp. (PNWC) of Vancouver, BC, to evaluate the River Valley mafic intrusion, 50 km east of Sudbury. The intrusion is a layered gabbro-anorthosite complex, with elevated PGM values near its contact with the country rock. Mustang Minerals Corp. of Toronto, ON, and Impala Platinum Corp. of Johannesburg, South Africa, have joined forces to explore parts of the intrusion adjoining PNWC's license area (Mining Journal, 2000c).

Mustang also was exploring a second gabbro-anorthosite complex at East Bull Lake, 80 km west of Sudbury. Again, PGM values appear to be enriched at the margins of the intrusion (Mining Journal, 2000a).

Quebec.—Exploration activities have increased dramatically in parts of Quebec since the discovery of the Voisey's Bay deposit in neighboring Labrador and the startup of Falconbridge's Raglan Mine on the Ungava Peninsula.

The Raglan mining and milling complex completed its second full year of operation. The new nickel-copper mine is in the Nunavik region of northern Quebec—near Katinniq, at the tip of the Ungava Peninsula. Falconbridge spent C$25 million in 2000 to increase annual milling capacity from 800,000 t of ore to 1 Mt. In 2000, Raglan recovered 936,000 t of ore averaging 2.94% Ni and 0.86% Cu. This equated to a mine production of 23,089 t of nickel in concentrate. The nickel concentrate also contained 6,308 t of copper and 289 t of cobalt (Falconbridge Ltd., 2001, p. 18-19).

Falconbridge was hoping to eventually raise production capacity to 30,000 t of nickel in concentrate. At yearend 2000, Raglan had 19.5 Mt of proven and probable reserves, averaging 2.85 % Ni and 0.78% Cu. In addition to the reserves, Raglan had 2.74 Mt of indicated resources averaging 1.86% Ni and 0.69% Cu (Falconbridge Ltd., 2001, p. 13).

Manitoba.—Inco's Manitoba Division produced about 45,000 t of nickel, up 33% from 34,000 t in 1999 (McCutcheon, 2001). There were two principal mines—the Birchtree and Thompson. Inco has decided to deepen the Birchtree over the next 5 years and has begun resurveying the entire Thompson Nickel Belt (Inco Ltd., 2000b).

Canmine Resources Corp. continued to evaluate 2,000 square kilometers (km^2) of claims northeast and west of the Thompson Belt (Canmine Resources Corp., 1999b). In early 2000, Canmine transferred its interests in the BINCO project to a wholly owned subsidiary named BINCO Resources Corp. In March 1999, Canmine obtained 21-year renewable surface and mineral right leases on its Maskwa property in Nopiming Provincial Park from the Province of Manitoba (Canmine Resources Corp., 1999a).

Alberta.—Sherritt International Corp. continued to improve operations at its Fort Saskatchewan refinery. Finished nickel production was 28,070 t, slightly below the record of 28,643 t set in 1999 (Sherritt International Corp., 2001, p. 7). The bulk of the feedstock—nickel-cobalt sulfide precipitate—came from Metals Enterprise, a mining and concentrating operation at Moa in Cuba. Metals Enterprise is a 50-50 joint venture between Sherritt and the Government of Cuba.

China.—Recent advances in nickel and rare-earth electrochemistries have spurred several joint battery manufacturing projects in mainland China and Taiwan.

Evercel, Inc. of Danbury, CT, and Xiamen Three Circles Battery Co. have formed a joint venture to mass produce rechargeable nickel-zinc batteries in Fujian Province, China. The nickel-zinc batteries were being used to power bicycles, scooters, and small automobiles. The joint venture developed from a licensing agreement signed in February 1998 between Energy Research Corp. (ERC) and its two partners—the Formosa Plastics Group of Taiwan and the City of Xiamen, China (Energy Research Corp., 1998). Evercel was spun off from ERC on February 22, 1999, and shortly after opened its corporate headquarters along with a pilot production line at Danbury. The pilot production facility was producing sample quantities of the new batteries for field testing by prospective customers (Evercel, Inc., 1999a).

In August 1999, the joint venture, Xiamen Three Circles - ERC Battery Corp. Ltd., began manufacturing nickel-zinc batteries for electric bicycles at its brand-new facilities in Xiamen (Evercel, Inc., 1999b). The joint venture's first production order came from the Xiamen Bicycle Co. The Chinese post office department was using the electric bicycles to deliver mail. Evercel also assumed responsibility for the original licensing agreement with the Xiamen City government and Formosa Plastics. The original agreement allows Xiamen City and Formosa Plastics to jointly manufacture patented nickel-zinc batteries for electric and hybrid automobiles. Xiamen City's automotive company produces 30,000 conventional cars and trucks annually (Energy Research Corp., 1997).

Nan Ya Plastics Group, a Formosa Plastics subsidiary, has been developing new markets for nickel-zinc batteries on Taiwan. Xiamen Three Circles-ERC was hoping to sell a significant part of its production to Taiwanese electric scooter manufacturers. Taiwanese electric scooters are currently powered by lead-acid batteries. Comparison road testing of an Evercel scooter battery with an equivalent lead-acid battery was carried out by Taiwan Sanyang Industry Co., Ltd., one of the island's leading scooter manufacturers. The total life distance of the nickel-zinc-powered scooter was reportedly twice that of the lead-acid alternative (Evercel, Inc., 1999c). Recent environmental regulations adopted by the Taiwan Authorities require that, starting in 2000, 2% of the scooters manufactured on the island must be electrically powered. Electric scooter manufacturers were expecting to sell 33,000 battery packs in 2000.

On August 26, 1999, ECD and its subsidiary, Ovonic Battery, signed a cooperation and licensing agreement with Rare Earth High-Tech Co. Ltd. of Baotou. Rare Earth High-Tech is the largest producer of rare-earth elements in China and has mining and extraction operations in the Nei Mongol Autonomous Region. The company is a subsidiary of Baotou Iron and Steel Ltd. Rare Earth High-Tech and Ovonic Battery have agreed to jointly produce key materials for NiMH batteries. Proprietary

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rare-earth alloys are used as anodes in certain types of NiMH batteries. Several joint projects were planned, including production of hydrogen storage alloy powders, production of advanced nickel-hydroxide materials, and development of battery production equipment (Energy Conversion Devices, Inc., 1999).

Colombia.—On January 1, 2001, Billiton plc commissioned a second ferronickel production line at its Cerro Matoso S.A. (CMSA) subsidiary in northwestern Colombia. The commissioning marked the turning point in a 5-year project to expand operations and reduce production bottlenecks at the mining and smelting complex near Montelibano. Startup was achieved 3 months ahead of schedule, while costs were kept below the $353 million budgeted. Production on the second line was to be gradually increased over the next 18 months until the design capacity of 27,000 t/yr of contained nickel was reached. When the ramp-up is completed in July 2002, the two lines will have a combined production capacity of 55,000 t/yr of Ni in ferronickel (Billiton plc, 2001b). Each line has its own ore dryer, kiln, and smelting furnace, so that the ferronickel plant can now be operated continuously. The expanded plant reportedly has been designed so that intermediate products can be exchanged between the two lines if one of the kilns or furnaces should require repair or maintenance (Nacken, 2000).

Billiton launched the expansion project in February 1999 when the nickel market began to recover from 2 years of depressed prices. In December 1999, the company closed on a $240 million loan, completing financing of the project. ABN AMRO Bank N.V., Barclays Capital (a division of Barclays plc), and four other banks participated in arranging the loan syndication. The syndicated loan, technically termed a debt facility, will mature in mid-2005 (Billiton plc, 1999).

In 2000, CMSA produced 27,720 t of Ni in ferronickel and exported 26,192 t, building up stocks in the process. Only 2,016 t, or 8% of CMSA's total exports, went to the United States. About 70% of the ferronickel exports went to Europe (International Nickel Study Group, 2001b, p. 30).

Cuba.—Metals Enterprise, the joint venture of the Cuban Government and Sherritt, produced 29,520 t of nickel-plus-cobalt in mixed sulfides at Moa in 2000—a record high output. The material provided about 90% of the feed for the venture's Fort Saskatchewan refinery in Alberta (Sherritt International Corp., 2001, p. 7). Mixed sulfide production at Moa has increased 126% since 1994, the year when the joint venture was formed.

European Union.—Finland.—On April 5, 2000, OMG bought the Harjavalta nickel plant in Finland from Outokumpu Oyj. OMG paid Outokumpu EUR 180 million in cash, which was equivalent at the time to about $172 million (Outokumpu Oyj, 2000a, b). (On April 6, 1 EUR was quoted at US$0.9583). OMG wanted to integrate the nickel plant with its Kokkola cobalt and nickel chemicals plant. The Kokkola plant was spun off from Outokumpu in 1991 when Mooney Chemicals, Inc. and Outokumpu merged their chemical businesses to form OMG. The nickel smelter at Harjavalta was not part of the April 5 transaction. Outokumpu continued to operate the smelter, processing nickel-copper concentrates from Outokumpu's mines in Australia. Outokumpu was also toll processing concentrates for OMG.

In 2000, the Harjavalta nickel plant produced about 50,600 t of refined nickel. The bulk of the nickel was recovered from matte produced at Outokumpu's smelter. The Outokumpu matte was supplemented with matte imported from Australia (8,982 t gross weight) and Brazil (15,835 t gross weight). The nickel was leached from the matte and separated from the other transition metals by solvent extraction. Most of the nickel was recovered as cathode by electrowinning. Some of the nickel, however, was reduced with hydrogen and made into briquets.

The 180 employees working at the Harjavalta plant were transferred to OMG. OMG has begun to more closely integrate the nickel plant with its Kokkola chemical operations. OMG will continue to supply nickel to Outokumpu's stainless steel melt shop at Tornio. Outokumpu will remain a copper and zinc producer but is planning to eventually give up nickel production when ore reserves at its mines in Finland and Australia are depleted.

European Union.—Netherlands.—ELG Haniel GmbH handled about 1.2 Mt of stainless steel scrap and related materials in 1999. Approximately 790,000 t were processed in Europe, mostly in Germany. The company recently moved the scrap processing facilities of Jewometaal Stainless Processing B.V., its Dutch subsidiary, to a new location in the Port of Rotterdam. The relocation and upgrading cost EUR 8 million and will allow Jewometaal to recycle and transship 220,000 t/yr of stainless steel scrap (ELG Haniel GmbH, 2000, p. 32-33).

Indonesia.—PT International Nickel Indonesia Tbk. (PT Inco) and AnTam continued to add mining and smelting capacity to their operations on the island of Sulawesi. Total mine production in 2000 for all of Indonesia was 98,200 t of contained nickel. All of the ore came from laterite deposits. Several joint ventures have been formed to explore and/or develop promising properties in Maluku.

Sulawesi.—PT Inco completed its 4-year expansion project, increasing the production capacity of its Soroako smelter by 50% to 68,000 t/yr of Ni in matte. The company added a fourth electric furnace smelting line and upgraded the existing three lines. At the end of 2000, PT Inco had 101 Mt of proven and probable reserves in the Soroako area averaging 1.82% Ni. The company has an additional 130 Mt of indicated resources averaging 1.80% Ni and 171 Mt of inferred resources averaging 1.82% Ni (Inco Ltd., 2001, p. 26).

In July 1999, AnTam announced that it would begin building a third line at its ferronickel smelter at Pomalaa. The third line would raise the capacity of the smelter from 11,000 t/yr of Ni in ferronickel to 24,000 t/yr. Money for the expansion was to come from funds raised in the company's initial public offering of November 1997. If all goes well, the third line could be operational by 2002 (PT Aneka Tambang (Persero) Tbk., 1999).

Gag Island.—On July 12, Falconbridge Ltd. and BHP Ltd. of Melbourne, Australia, announced that they had tentatively formed a joint venture to further evaluate nickel laterite deposits on Gag Island. Several matters, however, had to be resolved before the joint venture could become effective (Falconbridge Ltd., 2000). Commercial arrangements with AnTam, BHP's Indonesian partner, needed to be clarified. There were also some outstanding issues involving management of the island's forests. When these matters are resolved, Falconbridge will be able to acquire a 37.5% interest in the nickel project by contributing $75 million for a feasibility study. Falconbridge would be responsible for managing the 2-year study. BHP's current 75% interest would be reduced to 37.5% upon completion of the feasibility study. AnTam would retain its current 25% interest in the project.

Gag Island is about 40 km southeast of Gebe Island, Maluku,

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where AnTam has one of its two principal nickel mines. BHP and AnTam have been working together on the Gag Island project since August 1996. BHP mining experts estimate that the Gag Island concession has 240 Mt of combined oxide and silicate resources averaging 1.35% Ni and 0.08% Co (BHP Ltd., 2000).

Halmahera Island.—Weda Bay Minerals Inc. of Vancouver, British Columbia, and AnTam have been jointly evaluating laterite deposits on Halmahera Island since May 1996. At least 11 areas between Cape Ulie and the Jira River were under investigation. The project is held under a contract of work between the Government of Indonesia and PT Weda Bay Nickel. PT Weda Bay Nickel is a joint venture of Weda Bay Minerals (90%) and AnTam (10%).

In February 2000, OMG agreed to work with Weda Bay Minerals and AnTam on the Halmahera project (OM Group Inc., 2000). OMG was to provide $18 million for a feasibility study in exchange for a 19.9% interest in Weda Bay Minerals. The feasibility study was scheduled to be completed in early 2002. If the feasibility study is positive, some of the Halmahera deposits could be in production as early as 2004. The nickel and cobalt would be recovered by pressure acid leaching. According to Weda Bay officials, the Halmahera deposits can supply the proposed PAL plant with 4 Mt/yr of ore for 30 years (Weda Bay Minerals Inc., 2000a, b). The PAL plant would produce some 30,000 t/yr of nickel and 3,000 t/yr of cobalt in value-added intermediate products (Metal Bulletin, 2000).

On August 16, Weda Bay Minerals announced that it had revised upward its estimates of nickel resources on the Halmahera concession by 73%. The total aggregate resource was now estimated to be 202 million dry tons of laterite averaging 1.37% Ni and 0.12% Co. The estimate included both indicated and inferred resources. The Santa Monica and Pinto deposits reportedly have an indicated resource, at a 1% nickel cutoff grade, of 60 million dry tons averaging 1.51 % Ni and 0.09% Co (Weda Bay Minerals Inc., 2000b).

New Caledonia.—Société Métallurgique le Nickel (SLN) accounted for 47% of New Caledonian mine production in 2000. The other 53% of mine production was divided among J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta (SMT), Société Minière du Sud Pacifique S.A. (SMSP), and several other independent mining companies. Mine production totaled 127,493 t on a contained nickel basis, up 16% from 110,062 t (revised) in 1999. In 2000, the French overseas territory exported 59,240 t of nickel in ore, which included 40,174 t of nickel in garnierite shipped to Japan and 19,066 t in limonitic laterites shipped to Australia. The remaining 68,300 t of nickel in ore was processed at the SLN smelter outside Doniambo (International Nickel Study Group, 2001b, p. 46-47).

SLN's Mining and Smelting Operations.—SLN operated the following four nickel mines: Thio, Kouaoua, Népoui-Kopéto, and Tiébaghi. (See figure 2.) A fifth mine, Kaala-Gomen (also known as Etoile du Nord), was operated by an SLN contractor. SLN's ore production was 5% greater than that of 1999. SLN and its subcontractors mined 3.71 Mt of wet lateritic ore, up from 3.52 Mt (revised). Garnierite ore accounted for 3.43 Mt or 92% of total production. The remaining 278,000 t was limonitic laterite. Eramet's management was evaluating a proposal to expand the new Tiébaghi Mine. In October, preparatory work was begun to resume mining laterites at Bonini in the Poro region. The Bonini mine site was abandoned in the early 1980s (Eramet Group, 2001, p. 30-35).

In 2000, the Doniambo smelter produced 43,914 t of nickel in ferronickel and 13,549 t of nickel in matte. The combined output of 57,463 t was an alltime high for Doniambo, edging out the previous record of 56,642 t set in 1999. A labor strike in February and March kept SLN from reaching its original production goal of 61,000 t. The refining capacity of the plant was 49,000 t/yr, while matte capacity was about 14,000 t/yr of contained nickel. SLN was planning to increase the annual capacity of Doniambo to 75,000 t sometime in 2004 or 2005 (Eramet Group, 2001, p. 30-35). Expansion of the smelter and improvement of operations at Tiébaghi were expected to cost a total of $180 million (Reuters Ltd., 2001).

The Paris-based Eramet Group controlled 60% of the shares of SLN, down from 90% in 1998. Eramet also had a 38.45% interest in Special Metals Corp.

Inco's Goro Project.—On December 13, Inco announced that it was hoping to complete its feasibility study of the Goro nickel-cobalt project by April 2001. The Goro deposits are at the southeastern tip of La Grande Terre, the main island. The mining and extraction project had advanced through several stages of planning and review since its inception in mid-1992. The Toronto-based nickel producer already had invested $50 million in an on-site pilot plant. The pilot-plant was being used to validate an advanced PAL process developed in-house to extract nickel and cobalt from lateritic ores. The plant was commissioned on October 22, 1999, and can process 12 metric tons per day of ore (Inco Ltd., 2000a, p. 24). Pilot-plant work to date indicates that the Inco process can be used successfully on a commercial scale. If financing can be arranged immediately after completion of the feasibility study, a full-size commercial facility could be operational by late 2004 or early 2005. The proposed mining and processing complex would have a production capacity of 54,000 t/yr of Ni in nickel oxide and 5,400 t/yr of Co in cobalt carbonate. A joint venture of Bechtel Overseas Corp. and Technip France S.A. would act as prime contractor during construction.

Inco was in the process of securing the necessary permits and clearances from the Government of New Caledonia to construct and operate the commercial facility. Inco and the Government have been discussing future taxes and financing arrangements for some time. The project's operating company, Goro Nickel S.A., is a wholly owned subsidiary of Compagnie Minière de Xere (CMX). CMX is a joint venture of Inco (85% equity) and Bureau de Recherches Géologiques et Minières—an agency of the French Government (15% equity).

Inco would continue to operate the Goro pilot plant after construction began and use the plant to train its future New Caledonian work force. The company has allocated $5 million for training and will build a training center near the pilot plant as part of the program. According to company officials, the Goro concession has more than 200 million dry tons of laterite ore, averaging 1.6% Ni and 0.17% Co. The initial mining zone has 47 Mt of proven and probable reserves (Inco Ltd., 2000e).

Inco was reportedly seeking a partner to help finance the $1.4 billion project and offset the investment risks (Platts Metals Week, 2001). Eramet has acknowledged that it has been contacted by Inco and has been evaluating the Canadian proposal. The Government of France, a stockholder in Eramet, has already committed $350 million for the Goro project.

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Nakéty PAL Project.—Argosy Minerals Inc. and SMT were considering building a PAL plant at Nakéty on the east-central coast of La Grand Terre. SMT, an independent New Caledonian mining company, has been operating on the island for more than a decade. Argosy, an Australian-Canadian exploration and development company, was created on May 7, 1999, when Argosy Mining Corp. and Calliope Metals Corp. merged. The new company was headquartered in Vancouver, British Columbia.

In 1995, Calliope agreed to purchase ore from SMT, which holds several mining concessions at Nakéty. In 1998, Calliope Metals shelved plans to build a PAL facility in the Australian State of Queensland. The PAL facility was to have used New Caledonian ore supplied by SMT. A feasibility study by Kvaerner Metals ASA, however, indicated that the cost of exporting wet, unbeneficiated ore to Queensland—about $1.00 per pound Ni—would make the project uneconomical. The study concluded that it would be more cost effective to build the same facility adjacent to SMT's concessions at Nakéty. Over the long term, the savings in ore shipping charges would outweigh any additional costs incurred in building and operating the PAL plant on La Grand Terre (Russell, 2001). In May 1998, Argosy Mining Corp. and SMT tentatively agreed to form a joint venture to explore the feasibility of a PAL plant at Nakéty (Argosy Minerals Inc., 2000b). Ore for the plant would come from four of SMT's concessions: Barbouille, Belle Asashi 2, Lucienne 2, and Lucienne 2H. Argosy has continued to honor the agreements of its two predecessors. In August 1999, Argosy formed a joint venture with SMT to evaluate the Nakéty concessions. More than 675 holes have been drilled within the Nakéty deposit to date.

Dynatec Engineering Corp. has performed extensive metallurgical tests on the Nakéty ores, and Kvaerner has completed a preliminary engineering study of the deposit. According to Resources Service Group (an Argosy contractor), the Nakéty deposit has measured, indicated, and inferred resources in excess of 48 million dry tons that are estimated to average 1.42% Ni and 0.12% Co. Measured and indicated resources consist of 21.0 million dry tons of limonitic ore averaging 1.33% Ni and 0.14% Co and an additional 13.5 million dry tons of underlying, magnesium-rich saprolitic ore averaging 1.83% Ni and 0.06% Co. SMT is currently mining the saprolite zone on a small scale for export. The limonitic ore is reportedly better suited than the saprolite for pressure acid leaching (Argosy Minerals Inc., 2001b).

On July 24, 2000, Argosy and SMT agreed to include SMT's concessions at Bogota in the joint-venture agreement. The Bogota concessions are in the Canala area, about 3 km northwest of the proposed plant site near Nakéty. The 40 Bogota concessions cover 53.9 km^2, compared with only 10.4 km^2 for Nakéty. Reconnaissance drilling carried out by SMT in 1995 suggests that laterite mineralization underlies much of the iron-rich cap rock that trends northwest along the entire 18-km length of the Bogota Peninsula. Exploration efforts to date have focused on an 11-km^2 target area in the southern part of the peninsula (Argosy Minerals Inc., 2000b). The additional resources may allow Argosy to increase the design capacity of the proposed refinery. A total of 196 holes were drilled on 8 of the 40 Bogota concessions between 1982 and 1995. In some places, the thickness of the limonitic zone exceeded 35 meters (m). The number of drill holes to date is insufficient to make a rigorous resource estimate for the Bogota area (Argosy Minerals Inc., 2001b).

Argosy, like Inco, was actively seeking a partner for its project. On July 25, 2001, Argosy announced that the Norilsk Nickel Mining and Metallurgical Co. of Russia had agreed to participate in the evaluation (Argosy Minerals Inc., 2001a). Norilsk Nickel would provide the $20 million needed for a new bankable feasibility study of the Nakéty-Bogota laterites and would reimburse Argosy for part of the development company's expenditures to date. In exchange, Norilsk Nickel would earn a 50% to 70% interest in the joint venture.

Koniambo Project.—In 1998, Falconbridge, SMSP, and Société de Financement et d'Investissement de la Province Nord formed a joint venture to develop a nickel mining and smelting complex in the North Province. The smelter would have a capacity of 54,000 t/yr of nickel in ferronickel and use lateritic ores from the Koniambo massif as feedstock. Falconbridge would be allowed to earn up to a 49% interest in the project. The diamond drilling program on the Koniambo massif was completed during 2000. A total of 70,600 m of rock were drilled between August 1998 and December 2000. Based on this latest drilling, geologists now estimate that the massif has 151 Mt of inferred resources averaging 2.58% Ni and 0.07% Co (Falconbridge Ltd., 2001, p. 27-28).

Philippines.—Three companies mined laterite ore in 2000—Hinatuan Mining Corp., Rio Tuba Nickel Mining Corp., and Taganito Mining Corp. Combined production amounted to 20,208 t of contained nickel, 63% more than in 1999. None of the ore was smelted in the Philippines. About 50% of the material was exported to Japan; another 25% went to Australia. The remaining 25% was stockpiled in anticipation of the construction of a proposed PAL operation (International Nickel Study Group, 2001a; b, p. 48).

Mindoro Island.—Crew Development Corp. of Vancouver, Canada, has been evaluating a large nickel laterite deposit on the island of Mindoro. Mindoro is separated from Luzon on the north by the Verde Island Passage and is about 120 km south of Manila. According to company officials, the laterite deposit has at least 72 million dry tons of resources grading 0.94% Ni and 0.06% Co (Crew Development Corp., 2000a, b). Crew acquired the 110-km^2 concession when it merged with Mindex ASA, a Norwegian exploration company, in 1999. The proposed $700 million mining and hydrometallurgical extraction complex could produce as much as 40,000 t/yr of nickel and 3,050 t/yr of cobalt over its 30 years of operation.

The nickel and cobalt would be recovered using PAL technology similar to that employed in Western Australia. Natural gas for the project would come from a pipeline proposed by Philippine National Oil Co. and Royal Dutch/Shell Group. The pipeline would transport gas to Batangas from a new offshore field being developed near Palawan Island. The pipeline would pass within 6 km of Crew's proposed plant site. The sulfur needed for leaching the nickel would come from the Pamplona sulfur deposit on the island of Negros, 300 km to the southeast. Crew already holds all of the rights to the Pamplona concession (Northern Miner, 2000a, b). Cash costs for the Mindoro operation potentially could be reduced by selling 126,000 t/yr of byproduct ammonium sulfate. The Philippine rice and sugar cane industries currently consume about 400,000 t/yr of imported ammonium sulfate.

Palawan Island.—On April 20, Sumitomo Metal Mining Co. Ltd. of Japan and Rio Tuba announced that they were launching a joint study to determine if high pressure acid leach technology

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could economically recover nickel at Rio Tuba's mine on Palawan Island (Reuters Ltd., 2000). The 500,000-t/yr open pit operation currently exports the bulk of its ore to Japan. The Rio Tuba ore typically grades 2.4% Ni. Philippine interests own 60% of Rio Tuba, while Japanese interests led by Pacific Metals Co. Ltd. (PAMCO) control the remaining 40%.

Sumitomo was hoping to complete the feasibility study by yearend 2000 and will be assisted by PAMCO. Sumitomo, the largest nickel producer in Japan, produces cathode and nickel salts at its Niihama refinery in Ehime Prefecture. PAMCO operates a ferronickel smelter at Hachinohe in Aomori Prefecture.

Russia.—The Russian Federation produced more more than 221,000 t of nickel in refined products (International Nickel Study Group, 2001b, p. 49-50). Norilsk Nickel was by far the largest producer in Russia, accounting for at least 218,000 t of nickel in metal or limited amounts of ferronickel, as well as 391,000 t of copper metal, and 4,650 t of cobalt. Norilsk Nickel produced 23% more nickel in 2000 than in 1996, when the company had a reported output of 177,185 t (Platt's Metals Week, 1998; Interfax International Ltd., 1999; RAO Norilsk Nickel, 1999a). A 1997 amendment to the Federation's Law on State Secrets prohibits Norilsk Nickel from divulging detailed production figures for its different subsidiaries.

RAO Norilsk Nickel.—In 2000, RAO Norilsk Nickel was the largest producer of nickel in the world, accounting for about 19% of total refinery production (RAO Norilsk Nickel, 2000a, b). The company was restructured in 2000 but continued to subsidize housing, the importation of food, and municipal services in the cities of Norilsk, Monchegorsk, and Zapolyarny. On January 4, 2000, officials of the LME agreed to accept two major nickel products made by Norilsk—full-size nickel cathode sheet (H-1) and full-size sheet with uncut edges (H-1Y).

In 1998, RAO Norilsk Nickel launched a 10-year development program aimed at modernizing operations on both the Kola Peninsula and the Taimyr Peninsula. The program required raising $3 billion to $5 billion from foreign investors. Norilsk Mining Co. was created to manage the A.P. Zavenyagin Norilsk Mining and Metallurgical Combine on the Taimyr Peninsula. The Kola Metallurgical and Mining Co, a second new entity, was to oversee the Pechenganickel Mining and Metallurgical Combine, the Severonickel Combine, and related activities on the Kola Peninsula (RAO Norilsk Nickel, 1999b).

The International Finance Company Bank, Norilsk's financial consultant, was to be responsible for developing the necessary market instruments needed to attract the initial $200 million. INTERROS Holding Co. of Russia would guarantee the investments under a "repo" agreement that could give INTERROS a 37.9% stake in Norilsk Mining Co. (Budrys, 2000). An additional $800 million would have to be raised before January 2003 if the program was to keep on schedule. The initial $200 million would be used to expand Norilsk Nickel's product line, improve sales to Russian consumers, create an overseas sales network, and improve the company's transport infrastructure.

The 10-year development program would allow Norilsk Mining Co. and Kola Metallurgical and Mining Co. to develop new levels in existing underground mines, construct new mines, and carry out local exploration work designed to transform inferred resources into measured reserves. If the plans are fully implemented, the Kola Combine would remain open past 2007 and possibly continue to operate until 2015 (RAO Norilsk Nickel, 2000b).

Expansion of Operations on the Taimyr Peninsula.—Mine development work to replace declining reserves has intensified, even though some 50 years of reserves still exist. The bulk of the Taimyr ores comes from the Oktyabr and the Talnakh deposits. The two deposits reportedly contain more than 35% of the world's nickel reserves (RAO Norilsk Nickel, 2000a). Production from the new Skalisty Mine will help offset declining output at some of the older mines. Increased production of disseminated "impregnation" ores and high-grade copper ores should compensate for declining production of high-nickel, massive sulfide ores.

The first stage in the development of the Pelyatka gas condensate field was completed in 2000. Construction of a pipeline from the field to Norilsk was well underway and was critical to the Taimyr expansion program. By yearend, 123 km of pipelines had been installed. The first gas was scheduled to reach Norilsk sometime in 2001. The initial gas flow was to be about 1.4 million cubic meters per day (RAO Norilsk Nickel, 2001, p. 10).

Questions About the Legitimacy of Norilsk's Privatization.—On June 20, 2000, a Moscow city prosecutor filed a lawsuit seeking to overturn the privatization of Norilsk Nickel (Mining Journal, 2000b). The lawsuit could complicate future company plans to raise capital for modernization and development. The lawsuit questioned the legality of the 1995 loans-for-shares program that preceded privatization of the giant parastatal enterprise. Under the program, the Russian Government used its equity in Norilsk Nickel as collateral to obtain a $170 million loan from United Export-Import Bank Open Joint Stock Co. (UNEXIM Bank). The original agreement gave UNEXIM Bank, now part of INTERROS, control of 51% of Norilsk Nickel's voting stock. The Russian Government never repaid the loan and Norilsk Nickel was subsequently sold at auction to ZAO SVIFT, an affiliate of UNEXIM Bank, for about $250 million.

UNEXIM Bank is rescheduling its foreign debt, undergoing restructuring, and may merge with ROSBANK, another INTERROS financial institution. On May 22, holders of UNEXIM Bank eurobonds ratified key parts of the restructuring plan. Fleming UCB is serving as financial adviser to UNEXIM Bank (INTERROS Holding Co., 2000).

Enterprises in the Ural Mountains.—The board of directors of RAO Yuzhural Nickel were considering turning over key assets—a nickel smelter and a hydrometallurgical plant used to produce cobalt—to Uraltransgaz, the company's gas supplier, in exchange for a forgiveness of debts. Uraltransgaz is already the largest shareholder in Yuzhural Nickel. The Orenburg Copper-Nickel Co., which has a 20% interest in the nickel producer, opposed the asset-debt swap. The Orenburg Copper Nickel Co. is a parastatal controlled by the Orenburg Regional Administration (Interfax International Ltd., 2000).

Venezuela.—The new Loma de Niquel mining and smelting complex was in the final stages of construction begun in October 1997. The site (formerly Loma de Hierro) is about 80 km southwest of Caracas. For more than 50 years, a string of companies had been evaluating the laterite deposit. The complex was designed to produce 17,500 t of Ni in ferronickel and began smelting ore in December 2000. Full capacity should be reached by 2001 (Minera Loma de Niquel, C.A., 2000).

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Yemen.—Canadian Mountain Minerals (Yemen) Ltd. (CMMY), a wholly owned subsidiary of Cantex Mine Development Corp., has been exploring a 40,000-km^2 area on the western margin of the Rubh al-Khali (*English* Great Sandy Desert) since January 1996 (Cantex Mine Development Corp., 1999a). In late 1999, CMMY drilled two holes into a portion of the Suwar ultramafic complex where the overlying soils were anomalously high in copper and nickel (Cantex Mine Development Corp., 1999b). On February 22, 2000, Cantex announced that both drill holes had intersected massive nickel and copper sulfide mineralization (Cantex Mine Development Corp., 2000a). The complex is located in the Maswar district of Hajjah Governorate, about 60 km west of Sana'a, the capital of Yemen. The principal rock types in the ultramafic complex are gabbro-norite, peridotite, and olivine gabbro.

The bulk of the sulfide mineralization in the two discovery holes was at depths of 40 to 70 m. The first hole intercepted 18.7 m of mineralization averaging 0.89% Ni, 0.67% Cu, and 0.046% Co. The second hole intercepted 22.1 m of mineralization averaging 1.41% Ni, 0.91% Cu, and 0.07% Co (Cantex Mine Development Corp., 2000a). The sulfide-rich sections also contained anomalous amounts of silver and PGM (Cantex Mine Development Corp., 2000d).

In the first half of 2000, CMMY drilled eight additional holes near the two discovery holes in an area now referred to as the Suwar north zone. Seven of the eight holes also intersected significant sulfide mineralization, with peak nickel values ranging from 0.43% to 1.64%. Mineralization was subsequently found in a second area, 1.6 km southwest of the two discovery holes. This second area is now referred to as the Suwar south zone. Three holes were drilled in the south zone where anomalous values of palladium and platinum as well as copper, nickel, and cobalt were present in soil and rock chips. One drill hole intersected a 6.7-m-thick sulfide section assaying 1.23% Ni, 0.45% Cu, 0.113% Co, and 2.02 g/t of silver (Cantex Mine Development Corp., 2000c).

On July 4, CMMY and Falconbridge International (Investments) Ltd. formed a joint venture to evaluate the Suwar discovery. Falconbridge International (Investments) is a wholly owned subsidiary of Falconbridge Ltd., one of the five largest nickel producers in the world. Under the joint-venture agreement, Falconbridge can earn up to a 60% working interest in the Suwar mining lease. The two Canadian partners are hoping to construct a mine and mill within 4 years if a proposed feasibility study is positive (Cantex Mine Development Corp., 2000b). In November, Falconbridge International was finishing up a ground electromagnetic survey of the Suwar complex but decided to suspend surveying until after the Ramadan holiday. The geophysical data were to be used to generate targets for the 2001 drilling program.

The Prime Minister of Yemen reportedly has commissioned the surveying and planning of a 42-km-long access road to the Suwar property. The access road would tie into an existing highway at a point 145 km from the Red Sea port of Hodeidah.

Current Research and Technology

Researchers Synthesize Organo-Nickel Compound that Behaves Like a Metal.—Japanese researchers have synthesized an organo-nickel compound that behaves like a metal. The new crystalline material reportedly is the first synthetic metal built from a single, neutral molecular component (Chemical and Engineering News, 2001). Previously synthesized molecular metals have had two or more components. The compound is referred to as $Ni(tmdt)_2$, where tmdt is trimethylene-tetrathiafulvalene-dithiolate. Resistivity and magnetic susceptibility measurements indicate that $Ni(tmdt)_2$ is metallic over a temperature range from 0.6 K (Kelvin) to room temperature, 296 K. Single crystal diffraction analysis revealed that $Ni(tmdt)_2$ has a triclinic crystal structure (Tanaka and others, 2001).

A conventional metal typically has good electrical and thermal conductivities, ductility, and reflectivity and usually exhibits high strength. These properties are related to a structure in which the positively charged ions are bonded through a field of free electrons (i.e., electron gas) which surrounds them. The $Ni(tmdt)_2$ molecule has 12 sulfur atoms bonded to carbon, forming a string of five-membered, heterocyclic rings. Because of this complex resonating ring structure, the new compound exhibits some of the characteristics of graphite and benzene.

The Japanese research team was composed of scientists from the Institute for Molecular Science in Okazaki and the Research Centre for Spectrochemistry at the University of Tokyo. The team focused on $Ni(tmdt)_2$ after finding in 1999 that an analogous nickel molecule, propylene-dithiotetrathiafulvalene-dithiolate [$Ni(ptdt)_2$], behaved like a semiconductor. The latest discovery may open new avenues for the preparation of molecule-based metals and novel superconductors.

Commercialization of Fuel Cells.—On September 21, Texaco Energy Systems, Inc. and ECD formed a 50-50 joint venture to commercialize regenerative fuel cells. ECD will provide proprietary technology and fuel cell development expertise. ECD has been developing an advanced automotive fuel cell that utilizes low-cost, nonnoble metal catalytic materials (Texaco Energy Systems, Inc. and Energy Conversion Devices, Inc., 2000).

In a fuel cell-powered automobile, hydrogen gas is used in place of gasoline. The fuel cell generates electric power for the automobile motor by combining the hydrogen with oxygen to form water vapor. The oxygen is in air drawn into the cell from the outside atmosphere. ECD has proposed storing the hydrogen in a metal hydride system the size of a conventional gasoline tank. The metal hydride matrix minimizes the possibility of a hydrogen explosion. For additional information, see Dunn (1999), Goes (1999), and Mangan (1999).

Outlook

There is little chance that ferronickel production in the United States can be revived in the near term. The use of PAL technology to recover nickel from lateritic ores in New Caledonia, the Philippines, and Western Australia is expected to keep nickel prices in check for at least a decade. The combined rate of refined nickel production for the three existing Australian PAL operations passed the 9,000 t/yr mark at the beginning of 2001 and was expected to keep growing for at least another 3 years, eventually surpassing 100,000 t/yr. Plans to develop additional lateritic nickel deposits in the Kalgoorlie region of Western Australia have accelerated since the Goldfields natural gas pipeline was completed in late 1996 (Griffiths, 2000). The availability of inexpensive natural gas from offshore fields on the North West Shelf of the Indian Ocean has made it economically possible to produce refined

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nickel at several other laterite deposits previously rejected because of their remote locations. At least part of the new ferronickel production from Cerro Matoso (Colombia) and Loma de Níquel (Venezuela) has begun to come to the United States. The proposed Goro and Koniambo projects in New Caledonia would put additional material into the U.S. supply line.

The immense resources of the Voisey's Bay nickel-copper-cobalt deposit in northeastern Labrador (Canada) continue to overshadow the market. Inco and the Provincial Government of Newfoundland could reach an agreement at any time on developing the sub-Arctic deposit. Depending on market conditions, the proposed Voisey's Bay mining and milling complex would be capable of producing from 60,000 to 123,000 t/yr of nickel in sulfide concentrates. In Ontario, Falconbridge and Inco continue to find new ore along the edges of the Sudbury Basin. In Manitoba and Quebec, exploration crews have identified several promising occurrences for future followup.

The long-term outlook for increased nickel consumption is extremely positive, despite the recent economic crises in East Asia. Several forces are helping to sustain long-term growth in nickel consumption. The population of the world continues to grow. Faster transport, the explosive expansion of telecommunications systems, and the globalization of markets are making society as a whole increasingly dependent on products fabricated from sophisticated starting materials, many of which contain significant quantities of nickel. A technologically advancing society is continually demanding new materials with improved resistance to corrosion and heat, again favoring nickel.

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. For the present, growing demand for stainless steel in China, Europe, and the Western Hemisphere has offset weak demand in Japan. Beginning in 2002, world stainless steel consumption is forecast to grow between 2% and 5% per year to the year 2007. After 2007, the growth rate could rise even more, perhaps reaching 9% at some point, if the Russian economy turns around. The outlook for stainless steel production in the United States remains positive despite the growth in steel imports. Stainless steel production in the United States could exceed 2.6 Mt in 2002—an all time high for the country. The austenitic share of the production is expected to remain unchanged at 59%. This percentage is lower than corresponding austenitic percentages reported by other member countries of the Organization for Economic Cooperation and Development because the U.S. automobile manufacturing industry consumes more than 500,000 t/yr of ferritic stainless, about 18% of total U.S. stainless consumption.

Demand for nickel-bearing superalloys is expected to grow. The aerospace industry has been gradually shifting from a defense-oriented market to one that is more evenly balanced between commercial and Government purchases. Advanced nickel and titanium alloys are increasingly being incorporated in aircraft.

Batteries now constitute a bigger market for nickel in the United States than either coinage or traditional copper-nickel alloys. The use of nickel in batteries is growing at a much faster rate than the use of nickel in steel, although the tonnages going into batteries are still small. The market for nickel-based batteries is expected to grow at least 6% per year during the next 10 years even if American and Japanese automobile manufacturers decide to substitute lithium-ion cells for nickel-metal hydride cells in their third-generation EVs or second-generation hybrid vehicles. Automobile manufacturers are considering replacing the current 12-volt electrical systems in vehicles with 42-volt systems. If adopted, the change could drastically change the types of metals used in batteries for conventional automobiles. A NiMH battery has a higher energy density and longer cycle life than its advanced lead-acid counterpart. Performance and environmental requirements favor the NiMH battery, but problems starting the automobile at low temperatures need to be resolved (Jouhanneaud, 2001).

References Cited

Aerospace Industries Association of America, Inc., 2001, Orders, shipments, and backlog of large commercial jet transport aircraft, first quarter 2001: Aerospace Industries Association of America, Inc., Statistics #01-27, series 23-02, June 5, 3 p.

Alcoa Inc., 2000a, Alcoa and Howmet enter into merger agreement: Pittsburgh, PA, Alcoa Inc. press release, June 2, 1 p.

———2000b, Alcoa completes acquisition of Cordant: Pittsburgh, PA, Alcoa Inc. press release, May 25, 1 p.

———2000c, Alcoa completes acquisition of Howmet: Pittsburgh, PA, Alcoa Inc. press release, June 20, 1 p.

Alcoa Inc. and Cordant Technologies, Inc., 2000, Alcoa to acquire Cordant Technologies: Pittsburgh, PA, and Salt Lake City, UT, Alcoa Inc. and Cordant Technologies, Inc. joint press release, March 14, 1 p.

Allegheny Technologies Inc., 1999a, Allegheny Technologies completes acquisition of stainless steel assets from Bethlehem Steel: Pittsburgh, PA, Allegheny Technologies Inc. press release, December 22, 1 p.

———1999b, Allegheny Technologies Inc. completes spin-offs: Pittsburgh, PA, Allegheny Technologies Inc. press release, November 30, 2 p.

———2001, Annual report—2000: Pittsburgh, PA, Allegheny Technologies Inc., 54 p.

Allegheny Teledyne Inc., 1999, Allegheny Teledyne announces major transformation: Pittsburgh, PA, Allegheny Teledyne Inc. press release, January 19, 3 p.

American Iron and Steel Institute, 2001a, Annual statistical report—2000: American Iron and Steel Institute, 130 p.

———2001b, Quarterly production of stainless and heat resisting raw steel (AIS 104)—Fourth quarter 2000: American Iron and Steel Institute, 2 p.

Anaconda Nickel Ltd., 1999a, Anaconda and Centaur enter strategic alliance for expansion of Cawse nickel operation: Anaconda Nickel Ltd. press release, November 18, 1 p.

———1999d, Historic first nickel production at Murrin Murrin: Perth, Western Australia, Anaconda Nickel Ltd. press release, May 7, 1 p. [Also available at URL http://www.anaconda.com.au/company_releases/070599_first_metal.htm].

———1999e, Quarterly report for the period ended March 31, 1999: Perth, Western Australia, Anaconda Nickel Ltd., 10 p. [Also available at URL http://www.anaconda.com.au/quarterly/march99qlymenu.htm].

———1999f, Quarterly report for the period ended September 30, 1999: Perth, Western Australia, undated, 8 p.

———2001, Anaconda Nickel Ltd. (Road show): Perth, Western Australia, February presentation, 28 slides.

Argosy Minerals Inc., 2000a, Annual report—1999: Vancouver, Argosy Minerals Inc., 25 p.

———2000b, Argosy adds significant additional mining concessions to its New Caledonian nickel laterite project: Vancouver, Argosy Minerals Inc. press release no. 00-03, July 24, 1 p.

———2001a, Argosy announces major joint venture partner for its Nakéty/Bogota project in New Caledonia: Vancouver, Canada, and Perth, Australia, Argosy Minerals Inc. press release, July 25, 1 p.

———2001b, New Caledonian nickel project: Vancouver, Canada, Argosy Minerals Inc. undated information bulletin, 5 p.

Atchison Casting Corp., 2000, Form 10-K for the fiscal year ended June 30, 1999: Atchison, KS, Atchison Casting Corp., 21 p.

———2001, 2000 Amended annual report: Atchison, KS, Atchison Casting Corp., 69 p.

AvestaPolarit Oyj Abp, 2001, AvestaPolarit/Outokumpu Steel annual results for 2000: Stockholm, Sweden, AvestaPolarit Oyj Abp press release, January 22, 11 p.

Avesta Sheffield AB, 2000, European Commission clears the proposed merger

Digitized by Google

between Avesta Sheffield and Outokumpu Steel: Stockholm, Sweden, Avesta Sheffield AB press release, December 4, 1 p.
———2001, Year-end report for April-December 2000: Stockholm, Sweden, Avesta Sheffield AB press release, February 22, 10 p.
Barozzi, Stefano, 1997, Metal recovery from steel wastes by the Inmetco process: Steel Times, v. 225, no. 5, May, p. 191-192.
Billiton plc, 1999, Finalisation of Cerro Matoso debt facility: London, UK, Billiton plc press release, December 14, 1 p.
———2000, Operating review/Nickel *in* Annual report—2000: London, Billiton plc, unpaginated 6 page section.
———2001a, Billiton unit buys stake in Ravensthorpe: London, UK, Billiton plc press release, March 9, 1 p.
———2001b, First ferronickel produced at Cerro Matoso's Line Two: London, UK, Billiton plc press release, January 3, 1 p.
BHP Ltd., 2000, BHP announces discussions on Gag Island nickel project: Melbourne, Australia, BHP Ltd. press release no. 72/00, July 12, 2 p.
Budrys, Aleksandras, 2000, Russia—Russian Norilsk seeks $1 BLN over next two years: Reuters Ltd. wire story from Moscow, May 18, 1 p.
Canmine Resources Corp., 1999a, Canmine and Province of Manitoba sign long-term surface and mineral right leases to advance major cobalt and nickel projects: London, Canada, Canmine Resources Corp. press release, March 1, p. 1.
———1999b, Mining & exploration—Project portfolio: London, Canada, Canmine Resources Corp., August 24, 8 p. [Also available at URL http://www.canmine.com/projects.htm].
Cantex Mine Development Corp., 1999a, Cantex Mine Development Corp.—New precious and base metal occurrences in Yemen—Drilling planned for 1999: Kelowna, Canada, Cantex Mine Development Corp., February 2, 4 p.
———1999b, Cantex progress report on two of four base and precious mineral discoveries planned for drilling in Yemen: Kelowna, Canada, Cantex Mine Development Corp., November 30, 1 p.
———2000a, Assay results from the first discovery holes into the Suwar sulphide deposit, Yemen: Kelowna, Canada, Cantex Mine Development Corp., February 22, 2 p.
———2000b, Cantex subsidiary signs major agreement with Falconbridge subsidiary to develop the Suwar nickel-copper-cobalt +/- platinum-group metal deposit, Yemen: Kelowna, Canada, Cantex Mine Development Corp., July 4, 1 p.
———2000c, New drill results—Cantex Suwar project, Yemen: Kelowna, Canada, Cantex Mine Development Corp., June 20, 3 p.
———2000d, Suwar copper-nickel-cobalt-silver-gold-platinum-group element (PGE) discovery, Yemen: Kelowna, Canada, Cantex Mine Development Corp., August 8, 3 p.
Chemical and Engineering News, 2001, Unimolecular metal created: Chemical and Engineering News, v. 79, no. 3, January 15, p. 11.
Comet Resources Ltd., 2000, Ravensthorpe nickel project—Project summary: Perth, Australia, Comet Resources Ltd., October, 23 p.
Comet Resources NL, 1999, [Australian Stock Exchange announcement—Ravensthorpe nickel project]: Comet Resources NL press release, September 14, 2 p.
Crew Development Corp., 2000a, Crew Development Corporation commences bankable feasibility study on the Mindoro nickel project: Vancouver, Crew Development Corp. press release, June 21, 3 p.
———2000b, Mindoro nickel/cobalt project: Vancouver, Crew Development Corp., 4 p.
Donner Minerals Ltd., 1999, News release—[Innu Nation and South Voisey's Bay exploration program]: Vancouver, Donner Minerals Ltd. press release, July 6, 2 p.
Dunn, James, 1999, Rocket science, *in* Electric and Hybrid Vehicle Technology International '99: Dorking, United Kingdom, UK and International Press, p. 88-92.
Electric Vehicle Association of the Americas, 2001, EV market information—Battery electric light-duty passenger vehicle sales/leasing (1996-2000) and U.S. hybrid-electric vehicle sales/leasing (1999-2001): Washington, DC, Electric Vehicle Association of the Americas, October 15, 2 tables.
ELG Haniel GmbH, 2000, Annual report—1999: Duisburg, Germany, ELG Haniel GmbH, 74 p.
Energy Conversion Devices, Inc., 1999, ECD/Ovonic Battery sign major battery project in China: Troy, MI, Energy Conversion Devices, Inc. press release, September 2, 2 p.
———2001, Form 10-Q for the quarter ended December 31, 2000: Energy Conversion Devices, Inc., 37 p.
Energy Research Corp., 1997, Energy Research Corp. signs a memorandum of understanding for electric vehicle battery production in the People's Republic of China: Danbury, CT, Energy Research Corp. press release, December 3, 3 p.
———1998, Energy Research licenses nickel-zinc battery technology for electric vehicles in Asia: Energy Research Corp. press release, February 24, 2 p.
Eramet Group, 2001, Annual report—2000: Eramet Group, 70 p.
Evercel, Inc., 1999a, Evercel, Inc. opens pilot production and R&D facility in Danbury, CT: Danbury, CT, Evercel, Inc. press release, May 26, 3 p.
———1999b, Production starts for Evercel; bicycles and scooters first: Danbury, CT, Evercel, Inc. press release, August 10, 3 p.
———1999c, Electric scooter road test; Evercel patented nickel zinc vs. lead acid: Danbury, CT, Evercel, Inc. press release, August 12, 3 p.
Falconbridge Ltd., 2000, Falconbridge confirms tentative agreement on Gag Island nickel project: Toronto, Falconbridge Ltd. press release, July 12, 1 p.
———2001, Annual report—2000: Toronto, Falconbridge Ltd., 57 p.
Ford Motor Co. and Baker Electromotive, 1999, US Postal Service awards Ford Motor Company largest ever electric vehicle order: Washington, DC, Ford Motor Co. and Baker Electromotive joint press release, December 22, 2 p.
Goes, Friedrich, 1999, Cell of the century?, *in* Electric and Hybrid Vehicle Technology International '99: Dorking, United Kingdom, UK and International Press, p. 94-97.
Griffiths, Clive, 2000, Western Australia's nickel industry: The Hague, the Netherlands, guest presentation to the Statistics Committee, 2000 annual meeting of the International Nickel Study Group, April 13, 12 p. plus 14 view graphs.
Hagopian, Arthur, 1999, Anaconda warming up for Murrin Murrin output: American Metal Market, v. 107, no. 87, May 6, p. 5.
Heilprin, John, 2001, Little change in fuel economy—Small fraction of 2002 vehicles achieve 30 miles per gallon: Washington Post, October 10, p. E13.
Inco Ltd., 1999, Annual report—1998: Toronto, Inco Ltd., p. 20-21.
———2000a, Form 10-K for the fiscal year ended December 31, 1999: Toronto, Inco Ltd., 121 p.
———2000b, Inco announces U.S. $48 million deepening of Birchtree Mine in Manitoba: Toronto, Inco Ltd. press release, February 14, 1 p.
———2000d, Inco reports strong exploration results for high-grade discovery near Sudbury: Toronto, Inco Ltd., April 12, 1 p.
———2000e, Inco to proceed with next phase of Goro nickel project: Noumea, New Caledonia, Inco Ltd. press release, December 13, 2 p.
———2000f, Inco unable to reach agreement with Newfoundland and Labrador on Voisey's Bay: Toronto, Inco Ltd. press release, January 11, 2 p.
———2001, 2000 annual report: Toronto, Inco Ltd., 78 p.
Interfax International Ltd., 1999, Norilsk Combine raise output in 1998: Interfax International Ltd. Mining and Metals Report, v. 8, no. 10 (365), March 5, p. 9.
———2000, Yuzhuralnikel shareholders vote for asset-debt swap: Interfax International Ltd. Mining and Metals Report, v. 9, no. 21 (432), June 30-July 6, p. 11.
International Nickel Study Group, 2001a, World directory of nickel production facilities—Update 2001: The Hague, the Netherlands, International Nickel Study Group, July, unpaginated.
———2001b, World nickel statistics—Monthly bulletin: The Hague, the Netherlands, International Nickel Study Group, v. 11, no. 9, September, 80 p.
INTERROS Holding Co., 2000, Holders of UNEXIM Bank eurobonds ratify restructuring: Moscow, INTERROS Holding Co. press release, May 22, 1 p.
Jouhanneaud, Paul, 2001, Nickel and battery—From portable to automotive: The Hague, the Netherlands, guest presentation to the Statistics Committee, 2001 annual meeting of the International Nickel Study Group, April 26, 18 view graphs.
Juusela, Jyrki, 2000, Repositioning Outokumpu for strong growth as a leading metals and technology group: Espoo, Finland, Outokumpu News, no. 2/2000, December, p. 4-6.
Mangan, Michael, 1999, Hail and pace, *in* Electric and Hybrid Vehicle Technology International '99: Dorking, United Kingdom, UK and International Press, p. 98-100.
McCutcheon, Bill, 2001, Nickel, *in* Canadian Minerals Yearbook, 2000: Natural Resources Canada, in press.
Metal Bulletin, 2000, OMG invests in Weda Bay Ni and Co project: Metal Bulletin, no. 8455, March 2, p. 8.
Minera Loma de Niquel, C.A., 2000, Loma de Níquel project: Minera Loma de Niquel, C.A. handouts, July, 17 p.
Mining Journal, 1999a, Anaconda takes control of Bulong...: Mining Journal, v. 333, no. 8555, October 29, p. 337, 340.
———1999b, Australian nickel renaissance: Mining Journal, v. 333, no. 8552, October 8, p. 286-287.
———1999c, Bulong produces first nickel: Mining Journal, v. 332, no. 8523, March 12, p. 173.
———1999d, Partner for Ravensthorpe: Mining Journal, v. 333, no. 8557, November 12, p. 385-386.
———2000a, East Bull Lake intercepts: Mining Journal, v. 334, no. 8574, March 17, p. 213.
———2000b, Norilsk challenge: Mining Journal, v. 334, no. 8588, June 23, p. 479.

Digitized by Google

———2000c, PGM exploration accelerates: Mining Journal, v. 334, no. 8578, April 14, p. 285-286.
Nacken, Bert, 2000, Cerro Matoso, *in* Seminar on Billiton Nickel, London, March 24, 2000, Proceedings: London, Billiton plc, CD-ROM.
Napier, D.H., 2000, 2000 Year-end review and 2001 forecast—An analysis: Aerospace Industries Association of America, Inc., 3 p.
Nickel Development Institute, 1999a, Nickel industry opposes sale of "low-level" radioactive scrap: Toronto, Nickel Development Institute press release, December 21, 12 p.
———1999b, USA—Radioactively contaminated scrap: Nickel Development Institute, Communiqué, no. 26, November, p. 2.
Northern Miner, 2000a, Crew acquires sulphur deposit in Philippines: Northern Miner, v. 86, no. 8, April 17-23, p. 15.
———2000b, Crew advances globally diverse assets: Northern Miner, v. 86, no. 10, May 1-7, p. 6, 19.
Nuclear News, 2000, Recycling—Richardson halts plans to reuse contaminated metal: American Nuclear Society, Nuclear News, v. 43, no. 2, February, p. 34, 35.
OM Group Inc., 2000, OM Group announces letter of agreement to jointly develop long term nickel feed source: Cleveland, OH, OM Group Inc. press release, February 25, 1 p.
Outokumpu Oyj, 1998a, Getting in mint condition for Europe: Outokumpu Oyj, Outokumpu News, no. 2, p. 18-19.
———1998b, Outokumpu and Mint of Finland to cooperate in producing Euro coins: Espoo, Finland, Outokumpu Oyj press release, May 15, 2 p.
———2000a, Outokumpu to sell Harjavalta nickel plant: Espoo, Finland, Outokumpu Oyj press release, February 23, 1 p.
———2000b, Sale of Outokumpu's Harjavalta nickel plant to OM Group concluded: Espoo, Finland, Outokumpu Oyj press release, April 5, 1 p.
———2001, AvestaPolarit is born: Espoo, Finland, Outokumpu Oyj press release, January 22, 2 p.
Outokumpu Oyj and Avesta Sheffield AB, 2000, Outokumpu and Avesta Sheffield form new leading stainless steel company: Espoo, Finland, and Stockholm, Sweden, Outokumpu Oyj and Avesta Sheffield AB joint press release, September 28, 16 p.
Platt's Metals Week, 1998, Norilsk Nickel production soars as profits dive: Platt's Metals Week, v. 69, no. 25, June 22, p. 9-10.
———1999a, Anaconda eyes Murrin Murrin, Bulong nickel expansions: Platt's Metals Week, v. 70, no. 44, November 1, p. 2-3.
———1999b, Murrin Murrin nickel project produces first metal: Platt's Metals Week, v. 70, no. 19, May 10, p. 15.
Platts Metals Week, 2001, Eramet is "potential partner" for Inco's Goro nickel: Platts Metals Week, v. 72, no. 31, July 30, p. 1, 5-6.
Precision Castparts Corp., 2000, Annual report—2000: Portland, OR, Precision Castparts Corp., 44 p.
———2001, Annual report—2001: Portland, OR, Precision Castparts Corp., 44 p.
Preston Resources Ltd., 1999, Marlborough nickel project update, September 1999: Preston Resources Ltd. press release, September, 5 p.
PT Aneka Tambang (Persero) Tbk., 1999, Construction of AnTam's third ferronickel production line at Pomalaa, *FeNi III*, to begin by the end of 1999: Jakarta, Indonesia, PT Aneka Tambang (Persero) Tbk. press release, July 27, 2 p.
RAO Norilsk Nickel, 1999a, Norilsk Nickel announces interim results for 1999: Moscow, RAO Norilsk Nickel press release, December 30, 4 p.
———1999b, Norilsk Nickel is one of Russia's top ten companies—By several yardisticks [sic] applied to 1998 results: Moscow, RAO Norilsk Nickel press release, October 7, 1 p.
———1999c, Norilsk Nickel maps out its development to 2010: Moscow, RAO Norilsk Nickel press release, February 10, 1 p.
———2000a, Into the new millennium—Norilsk Nickel today: Moscow, RAO Norilsk Nickel booklet, 32 p.
———2000b, Norilsk Nickel to develop its mineral resources on the Kola Peninsula: Moscow, RAO Norilsk Nickel press release, June 20, 1 p.
———2001, Annual report—2000: Moscow, RAO Norilsk Nickel, 52 p.
Reuters Ltd., 2000, Japanese eye nickel project: Reuters Ltd., April 21, 1 p.
———2001, Eramet okays New Caledonia nickel expansion: Reuters Ltd., wire story from Noumea, New Caledonia, June 29, 1 p.
Russell, David, 2001, The development of the Nakéty/Bogota project, Northern Province, New Caledonia: Noumea, New Caledonia, Argosy Minerals Inc., June presentation, 41 slides.
Sherritt International Corp., 2001, Annual report—2000: Sherritt International Corp., 42 p.
Slater Steel Inc., 2000a, Slater Steel announces agreement to acquire operating divisions and other assets of Atlas Steels: Mississauga, Canada, Slater Steel Inc. press release, June 15, 4 p.
———2000b, Slater Steel completes acquisition of Atlas Specialty Steels, Atlas Stainless Steels and other Atlas Steels' assets: Mississauga, Canada, Slater Steel Inc. press release, August 1, 2 p.
———2000c, Slater Steel initiates preliminary phase of Atlas integration: Mississauga, Canada, Slater Steel Inc. press release, August 23, 2 p.
Slater Steels Corp., 2000a, Slater Steels Corporation, Fort Wayne Specialty Alloys division files antidumping petition: Washington, DC, Slater Steels Corp. press release, August 21, 2 p.
———2000b, U.S. International Trade Commission votes on Slater Steels Corporation, Fort Wayne Specialty Alloys division antidumping petition: Washington, DC, Slater Steels Corp., September 29, 1 p.
Specialty Steel Industry of North America, 2000, Six-month specialty steel data reflect increases in imports and import penetration: Washington, DC, Specialty Steel Industry of North America press release, September 1, 5 p.
———2001, Specialty steel imports in 2000 set record. Total stainless steel bar, rod, & wire imports captured more than half of the U.S. market: Washington, DC, Specialty Steel Industry of North America press release, March 14, 8 p.
Stillwater Mining Co., 2001a, Annual report—2000: Stillwater Mining Co., 62 p.
———2001b, Form 10-K for the fiscal year ended December 31, 2000: Stillwater Mining Co., 68 p.
Strategic Minerals Corp., 1999, Construction underway on new plant to recover vanadium and other metals from spent catalysts: Strategic Minerals Corp. press release, April 8, 1 p.
Tanaka, Hisashi, Okano, Yoshinori, Kobayashi, Hayao, Suzuki, Wakako, and Kobayashi, Akiko, 2001, A three-dimensional synthetic metallic crystal composed of single-component molecules: Science, v. 291, no. 5502, January 12, p. 285-287.
Texaco Energy Systems, Inc. and Energy Conversion Devices, Inc., 2000, Texaco and Energy Conversion Devices, Inc. form joint fuel cell venture: Troy, MI, Texaco Energy Systems, Inc. and Energy Conversion Devices, Inc. joint press release, September 21, 2 p.
Texaco Inc. and Energy Conversion Devices, Inc., 2000, Texaco closes purchase of 20 percent interest in Energy Conversion Devices, Inc.: Troy, MI, Texaco Inc. and Energy Conversion Devices, Inc. joint press release, June 1, 1 p.
U.S. Department of Energy, 2000, Energy Secretary Richardson blocks nickel recycling at Oak Ridge: U.S. Department of Energy press release, January 12, 1 p.
Washington Post, 2000, DOE stops sale of radioactive scrap nickel: Washington Post, January 13, p. A4.
Weda Bay Minerals Inc., 2000a, Weda Bay Minerals Inc.—Strategic partnership with OM Group announced: Weda Bay Minerals Inc. press release, February 25, 3 p.
———2000b, Weda Bay Minerals increases nickel resource: Vancouver, Weda Bay Minerals Inc. press release, August 16, 2 p.
Western Australian Department of Resources Development, 1999, Western Australian nickel review—1999: Western Australian Department of Resources Development, 64 p.
Whyte, James, 1999, Inco, government talks hint at deal—Hydrometallurgical plant may meet processing demand: Northern Miner, v. 85, no. 40, November 29-December 5, p. 1, 14, 18.
WMC Ltd., 2001a, Annual report 2000—Concise: Southbank, Australia, WMC Ltd., 49 p.
——2001b, 5 year production: Southbank, Australia, WMC Ltd., 2 p. [Also available at URL http://www.wmc.com/investor/5yearpro.htm].
World Bureau of Metal Statistics, 2000, Annual stainless steel statistics: Ware, United Kingdom, World Bureau of Metal Statistics, 123 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Nickel. Ch. in Minerals Commodity Summaries, annual.
Nickel. Ch. in Minerals Yearbook, annual.
Nickel. Ch. in United States Mineral Resources, U.S. Geological Survey Professional Paper 820, 1973.
Nickel. International Strategic Minerals Inventory Summary Report, Circular 930-D, 1985.
Nickel. Mineral Industry Surveys, monthly.

Other

American Metal Market, daily.
Chemical Abstracts.
Chemical and Engineering News, weekly.

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Company annual reports.
Engineering and Mining Journal, monthly.
International Nickel Study Group (The Hague).
Metal Bulletin [London], semiweekly and monthly.
Mining Journal, weekly, and Mining Annual Review.
Natural Resources—Canada (Ottawa).
Nickel. Ch. in Mineral Facts and Problems. U.S. Bureau of Mines Bulletin 675, 1985.
Nickel Development Institute (Toronto).
Nickel Producers Environmental Research Association.
Platts Metals Week, weekly.
Roskill Information Services Ltd. Reports (London).
World Bureau of Metals Statistics (Ware, United Kingdom).

TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Mine production	1,330	--	--	--	--
Plant production	15,100	16,000	4,290	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	48,800	58,200	52,700	58,600	71,700
From nonferrous scrap	10,500	10,200	10,400	12,400 r/	12,200
Shipments of purchased scrap 2/	84,900	97,600	89,700 r/	93,000 r/	123,000
Exports:					
Primary	13,100	16,400	8,440	7,440 r/	8,150
Secondary	33,600	40,200	35,100	31,400	49,900
Imports for consumption:					
Ore	15,000	17,600	1,420	--	--
Primary	142,000	147,000	148,000	139,000	156,000
Secondary	8,060	11,000	8,500	9,480	10,700
Consumption:					
Reported:					
Primary	118,000 r/	120,000 r/	116,000 r/	116,000 r/	115,000
Secondary (purchased scrap) 3/	59,300	68,400	63,100 r/	71,000	84,000
Total	177,000 r/	188,000 r/	179,000 r/	187,000 r/	199,000
Apparent:					
Primary	146,000	154,000 r/	149,000 r/	140,000 r/	147,000
Secondary (purchased scrap) 4/	33,700	37,700	36,900 r/	49,400 r/	42,000
Total	180,000	192,000 r/	186,000 r/	190,000 r/	189,000
Apparent primary plus reported secondary	206,000	222,000 r/	212,000 r/	211,000 r/	231,000
Stocks, yearend:					
Government	15,900	8,530	2,600	--	--
Producers and traders	13,300	12,600	13,100	12,700	12,300
Consumer, primary	9,270	10,400 r/	10,500 r/	4,850 r/	6,490
Consumer, secondary	4,230	5,770	5,460 r/	5,070	7,860
Total	42,700	37,300	31,700 r/	22,600 r/	26,600
Employment, yearend:					
Mine	8	7	7	1	1
Smelter	253	264	6	6	(5/)
Port facility	23	22	1	1	--
Price, cash, London Metal Exchange:					
Per metric ton, average annual	$7,501	$6,927	$4,630	$6,011	$8,638
Per pound, average annual	$3	$3	$2	$3	$4
World, mine production	1,060,000	1,120,000 r/	1,130,000 r/	1,120,000	1,250,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

2/ Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

3/ More nearly represents amount consumed than does apparent secondary consumption.

4/ Internal evaluation indicates that apparent secondary consumption is considerably understated.

5/ The smelter at Riddle, OR, was decommissioned in 2000.

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TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons of contained nickel)

	1999	2000
Kind of scrap:		
Aluminum-base 2/	4,450	4,290
Copper-base	2,860	3,310
Ferrous-base 3/	58,600	71,700
Nickel-base	5,120 r/	4,620
Total	71,000	84,000
Form of recovery:		
Aluminum-base alloys	4,450	4,290
Copper-base alloys	5,160 r/	5,300
Ferrous alloys	58,600	71,800
Nickel-base alloys	2,780 r/	2,610
Miscellaneous and unspecified	2	1
Total	71,000	84,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.
3/ Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM 1/

(Metric tons of contained nickel)

Form	1999	2000
Primary:		
Metal	95,600 r/	94,600
Ferronickel	12,800 r/	13,500
Oxide and oxide sinter 2/	5,160	3,610
Chemicals	1,660	1,340
Other	1,200 r/	1,590
Total	116,000 r/	115,000
Secondary (scrap) 3/	71,000	84,000
Grand total	187,000 r/	199,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes chemical-grade oxide.
3/ Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
U.S. CONSUMPTION OF NICKEL IN 2000, BY USE 1/

(Metric tons of contained nickel)

Use	Metal	Ferro-nickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total 2000	Grand total 1999
Cast irons	54	W	--	--	60	114	54	168	495 r/
Chemicals and chemical uses	347	W	W	644	--	991	--	991	1,580 r/
Electric, magnet, expansion alloys	479	--	--	--	--	479	W	479	525 r/
Electroplating (sales to platers)	15,600	--	--	39	W	15,700	--	15,700	15,400 r/
Nickel-copper and copper-nickel alloys	5,570	W	W	--	16	5,590	4,370	9,960	10,500
Other nickel and nickel alloys	15,500	67	W	--	89	15,700	2,510	18,200	15,200
Steel:									
Stainless and heat resistant	21,100	13,200	3,360	W	153	37,800	70,400	108,000	102,000 r/
Alloys (excludes stainless)	5,370	85	147	--	776	6,370	1,330	7,700	8,100 r/
Superalloys	18,900	--	W	W	441	19,400	W	19,400	18,900 r/
Other 2/	11,600	68	107	651	59	12,500	5,350	17,800	15,200 r/
Total	94,600	13,500	3,610	1,330	1,590	115,000	84,000	199,000	187,000 r/
Total all companies, apparent	XX	XX	XX	XX	XX	147,000	42,000	189,000	190,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol "W."

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TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM, DECEMBER 31 1/

(Metric tons of contained nickel)

Form	1999	2000
Primary:		
Metal	3,610 r/	4,720
Ferronickel	430 r/	768
Oxide and oxide sinter	390	610
Chemicals	224 r/	188
Other	194 r/	202
Total	4,850 r/	6,490
Secondary (scrap)	5,070	7,860
Grand total	9,920 r/	14,300

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Unwrought primary (contained nickel):				
Cathodes, pellets, briquets, shot	831	$6,610	1,690	$15,100
Ferronickel	59	161	37	202
Powder and flakes	909	14,200	1,260	18,700
Metallurgical-grade oxide	1,470	2,730	1,930	6,350
Chemicals (contained nickel):				
Catalysts	3,360	110,000	1,880	70,100
Salts 3/	803	6,860	1,350	13,800
Total	7,440	140,000	8,150	124,000
Unwrought secondary (contained nickel):				
Stainless steel scrap	19,500	151,000	35,100	310,000
Waste and scrap	12,000	40,300	14,800	60,900
Total	31,400	192,000	49,900	371,000
Grand total	38,900	332,000	58,100	495,000
Wrought (contained nickel):				
Bars, rods, profiles, wire	382	4,300	520	9,200
Sheets, strip, foil	280	4,700	741	13,000
Tubes and pipes	260	2,550	147	1,550
Total	,922	11,500	1,410	23,700
Alloyed (gross weight):				
Unwrought alloyed ingot	9,140	76,100	9,850	91,400
Bars, rods, profiles, wire	6,360	101,000	7,270	120,000
Sheets, strip, foil	7,430	90,500	7,930	112,000
Tubes and pipes	828	20,400	1,010	23,900
Other alloyed articles	3,550	82,400	2,670	86,500
Total	27,300	371,000	28,700	433,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.
3/ Excludes nickel carbonate (see Schedule B 2836.99.9050).

Sources: U.S. Census Bureau and Journal of Commerce.

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TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 2000, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, briquets (unwrought)	Powder and flakes	Ferro-nickel	Metallurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 2000	Total 1999	Wrought nickel 4/
Australia	--	1	--	--	11	1	3	16	28	28
Belgium	--	6	--	11	794	923	66	1,800	874	28
Brazil	3	19	--	6	--	74	47	149	38	9
Canada	347	456	31	1,820	8,770	3,500	551	15,500	13,400	239
China	1	3	--	--	149	1,770	64	1,980	732	17
Colombia	46	49	--	--	--	--	8	103	44	1
Finland	--	--	--	--	--	--	10	10	(5/)	--
France	295	86	--	--	16	10	37	444	130	15
Germany	1	99	6	1	623	97	126	953	627	54
India	--	5	--	1	73	1,230	28	1,340	296	4
Italy	1	27	--	17	13	11	9	78	25	25
Japan	22	48	--	(5/)	1,380	3,450	471	5,370	3,310	13
Korea, Republic of	6	29	--	1	1,580	13,500	92	15,200	8,080	34
Mexico	920	97	--	24	11	172	336	1,560	1,310	424
Netherlands	--	17	--	16	90	1,150	71	1,340	246	4
South Africa	--	(5/)	--	3	336	944	14	1,300	1,320	--
Spain	--	9	--	--	93	1,510	3	1,620	2,030	--
Sweden	--	5	--	(5/)	323	384	47	759	144	3
Taiwan	1	42	--	(5/)	12	5,970	180	6,210	4,050	18
United Kingdom	13	68	--	--	267	65	27	440	743	192
Venezuela	--	1	--	--	--	5	52	58	29	4
Other	33	192	--	34	266	319	989	1,830	1,460 r/	296
Total	1,690	1,260	37	1,930	14,800	35,100	3,230	58,100	38,900	1,410

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

3/ Chemical-grade oxide is included in the "Chemicals" category.

4/ Excluded from "Total."

5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Unwrought primary (contained nickel):				
Cathodes, pellets, briquets, shot	109,000	$607,000	119,000	$1,020,000
Ferronickel	14,300	73,000	16,400	125,000
Flakes	206	1,200	942	9,320
Powder	9,170	84,700	13,500	146,000
Metallurgical-grade oxide	3,270	20,500	2,540	27,200
Chemicals (contained nickel):				
Catalysts	996	47,600	1,690	61,700
Salts 3/	1,810	20,200	2,000	25,400
Total	139,000	854,000	156,000	1,410,000
Unwrought secondary (contained nickel):				
Stainless steel scrap	4,960	27,700	4,220	35,500
Waste and scrap	4,520	27,100	6,530	56,400
Total	9,480	54,800	10,700	91,900
Grand total	149,000	909,000	167,000	1,500,000
Wrought (contained nickel):				
Bars, rods, profiles, wire	535	4,950	438	6,370
Sheets, strip, foil	540	12,600	503	13,600
Tubes and pipes	11	382	51	452
Total	1,090	17,900	992	20,400

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Alloyed (gross weight):				
Unwrought alloyed ingot	2,360	26,400	4,710	61,800
Bars, rods, profiles, wire	6,320	70,700	7,270	85,000
Sheets, strip, foil	2,560	35,500	3,470	58,900
Tubes and pipes	1,230	21,500	2,040	32,400
Other	818	29,600	1,550	32,400
Total	13,300	184,000	19,000	270,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.
3/ Excludes nickel carbonate (see Harmonized Tariff Schedule of the United States 2836.99.5000).

Sources: U.S Census Bureau and Journal of Commerce.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 2000	Total 1999	Wrought nickel 4/
Australia	10,200	5,240	--	53	28	--	--	15,500	14,600	--
Austria	--	143	--	--	--	--	--	143	657	103
Belgium	--	8	--	--	121	--	380	509	488	--
Brazil	5,960	2	--	--	--	46	71	6,080	5,680	26
Canada	53,500	6,510	--	2,480	2,550	2,350	103	67,500	59,400	34
China	--	--	--	--	21	--	140	161	681	9
Colombia	--	--	2,020	--	--	13	--	2,030	1,840	--
Dominican Republic	--	--	7,990	--	--	17	--	8,010	7,550	--
Finland	3,400	841	--	--	--	--	630	4,870	5,010	--
France	2,280	1	--	--	1,100	3	262	3,640	2,720	61
Germany	43	28	--	--	800	8	309	1,190	785	513
Japan	2	30	--	4	88	70	1,110	1,300	843	130
Mexico	--	--	--	--	319	1,440	15	1,770	1,690	1
Netherlands 5/	1,570	40	--	--	40	9	386	2,050	315	--
New Caledonia	--	--	6,390	--	--	--	--	6,390	4,960	--
Norway	18,400	--	--	--	27	--	--	18,400	22,700	--
Russia	19,500	1,290	--	--	10	--	--	20,800	13,800	--
South Africa	144	60	--	--	--	--	40	244	826	--
United Kingdom	2,340	174	--	--	826	18	103	3,460	2,320	64
Zimbabwe	1,600	--	--	--	--	--	--	1,600	1,190	--
Other	188	76	--	--	603	245	140	1,250	670	50
Total	119,000	14,400	16,400	2,540	6,530	4,220	3,690	167,000	149,000	992

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.
3/ Primarily oxide, rondelles and sinter.
4/ Excluded from "Total."
5/ The different nickel metal products (cathode, powder, etc.) are apparently material that has transited through bonded warehouses in the Netherlands including warehouses overseen by the London Metal Exchange.

Source: U.S. Census Bureau.

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TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1996	1997	1998	1999	2000
Australia (content of concentrate)	113,134	123,372	143,513	127,000 r/	168,300
Botswana (content of ore milled)	21,910	19,860 r/	21,700 r/	33,733 r/	34,465
Brazil (content of ore)	25,245	31,936	36,764	41,522 r/	45,317
Burma (content of ore)	35 r/	38 r/	30 r/	76 r/	40
Canada (content of concentrate)	192,649	190,529	208,201	186,236 r/	190,728 p/
China e/	43,800	46,600	48,700	49,500 r/	51,100
Colombia (content of laterite ore)	27,700	31,230	29,422	39,274 r/	58,927
Cuba (content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor) 3/	51,220 r/	58,881 r/	64,752 r/	63,627 r/	68,305
Dominican Republic (content of laterite ore)	45,168	49,152	40,311 r/	39,997 r/	39,943
Finland (content of concentrate)	2,136	3,252	1,967	70 r/	2,600
Greece (content of laterite ore)	21,600 r/	18,419 r/	16,985 r/	16,050 r/	19,535
Indonesia (content of ore)	87,911	71,127	74,063	89,111 r/	98,200
Kazakhstan e/	7,000	7,000	-- r/	-- r/	3,000
Macedonia (content of ferronickel produced) e/	3,000	5,300	5,800	1,900	--
New Caledonia (content of ore)	122,486	136,467	125,319	110,062 r/	127,493
Norway (content of concentrate)	3,135	2,454	2,959	2,965 r/	2,538
Philippines	14,539	18,137 r/	12,840	14,300 r/ e/	23,500 e/
Russia e/	230,000	260,000	250,000	260,000	270,000
Serbia and Montenegro (content of ferronickel produced)	2,556	2,440	466	--	--
South Africa (content of concentrate)	33,861	34,830	36,679 r/	36,200 r/	36,616
Ukraine (content of ferronickel produced) e/	500	--	--	--	--
United States (content of local ore processed)	1,330	--	--	--	--
Venezuela (content of laterite ore)	--	--	--	--	2,472
Zimbabwe (content of concentrate)	11,561	12,963	12,872	11,164	8,160
Total	1,060,000	1,120,000 r/	1,130,000 r/	1,120,000	1,250,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through July 27, 2001.

3/ The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 25% for ammoniacal leach precipitate.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country and product 3/	1996	1997	1998	1999	2000
Albania, metal e/	50	--	--	--	--
Australia:					
Metal	61,377	58,824	64,322	75,952 r/	102,660
Unspecified	12,636	14,762	15,256	7,648 r/	9,155
Total	74,013	73,586	79,578	83,600 r/ 4/	111,815 4/
Austria, ferronickel e/	2,000	2,000	1,800	1,700	1,700
Brazil: 5/					
Ferronickel	9,091	9,350	8,077	6,502	6,347
Metal	7,849	8,849	13,006	16,429	16,906
Total	16,940	18,199	21,083	22,931	23,253
Canada, unspecified 6/	130,136	131,639	146,715	124,260 r/	134,224 p/
China, metal e/	44,600	43,300	40,100	44,400 r/	50,900
Colombia, ferronickel	22,934	25,171	28,143	28,345	27,720
Cuba, oxide sinter and oxides 7/	26,730 r/	33,571 r/	38,192 r/	37,510 r/	39,892
Dominican Republic, ferronickel	30,376	32,558	25,220	24,449	27,832

See footnotes at end of table.

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TABLE 11--Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country and product 3/	1996	1997	1998	1999	2000
Finland:					
Metal	28,815	34,228	46,200 r/	51,948 r/	50,619
Chemicals	4,508	4,990	4,518	4,143	3,711
Total	33,323	39,218	50,718 r/	56,091 r/	54,330
France:					
Metal	9,070	8,750	9,778	9,458	10,100
Chemicals	2,101	1,952	2,000 e/	2,244	2,200
Total 8/	11,171	10,702	11,778	11,702	12,300
Greece, ferronickel	17,801	17,610	15,005	12,964	17,470
Indonesia, ferronickel	9,553	9,999	8,452	9,205	10,111
Japan:					
Ferronickel	66,796	72,079	69,202	67,166 r/	73,448
Metal	26,564	26,889	29,397	30,481	36,230
Oxide sinter	34,772	26,899	25,435	34,482 r/	48,325
Chemicals	2,323	2,536	2,511	2,570	2,700
Total	130,455	128,403	126,545	134,699 r/	160,703
Korea, Republic of, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Macedonia, ferronickel e/	3,000	5,300	5,800	1,900	--
New Caledonia, ferronickel	42,173	44,312	44,491	45,289	43,914
Norway, metal	61,582	62,702	70,152	74,137 r/	58,679
Poland, chemicals 10/	359	364	376	396	430
Russia: e/ 11/					
Ferronickel	10,000	10,000	10,000	11,000	11,000
Metal	170,000	210,000	205,000	215,000	225,000
Oxide sinter	8,000	8,000	10,000	10,000	10,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	190,000	230,000	227,000	238,000	248,000
Serbia and Montenegro, ferronickel	2,556	2,440	466	--	--
South Africa:					
Metal	27,861 r/	28,830 r/	29,039	28,345	29,616
Chemicals 12/	6,000 r/	6,000	7,640 r/	7,855 r/	7,000
Total	33,861 r/	34,830 r/	36,679 r/	36,200 r/	36,616
Taiwan, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Ukraine, ferronickel e/	500	--	--	--	--
United Kingdom, metal	38,561	36,091	41,994 r/	39,467 r/	37,976
United States, ferronickel	15,100	16,000	4,290	--	--
Venezuela, ferronickel	--	--	--	--	40
Zimbabwe, metal:					
Refined from domestic materials 13/	9,694	10,300	8,732	9,106 r/	6,678
Toll refined from imported materials 14/	6,518	7,346	8,709	10,676	12,937
Total	16,212	17,646	17,441	19,782	19,615
Other, metal 15/	-- r/	-- r/	-- r/	-- r/	--
Grand total:	954,000 r/	1,020,000 r/	1,040,000 r/	1,050,000	1,120,000
Of which:					
Ferronickel	232,000	247,000	221,000	209,000 r/	220,000
Metal	493,000 r/	536,000 r/	566,000 r/	605,000 r/	638,000
Oxide sinter	69,500	68,500 r/	73,600 r/	82,000 r/	98,200
Chemicals	17,300 r/	17,800	19,000	19,200 r/	18,000
Unspecified	143,000	146,000	162,000	132,000 r/	143,000

See footnotes at end of table.

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TABLE 11--Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 27, 2001.
3/ In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 12.
4/ Includes estimated production of pressure acid leach operations.
5/ Brazil produced nickel carbonate (an intermediate product), in metric tons: 1996--9,210; 1997--10,487; 1998--13,133; 1999--17,153; and 2000--17,223.
6/ Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. See footnote 8.
7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 1996--24,490 (revised); 1997--25,310 (revised); 1998--26,561 (revised); 1999--26,118 (revised); and 2000--28,413. See table 12.
8/ Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.
9/ Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: the Republic of Korea: 1996--18,000 (revised); 1997--18,452 (revised); 1998--20,183; 1999--20,235; and 2000--29,890; and Taiwan: 1996--10,000; 1997-1998--10,5000; and 1999-2000--10,000.
10/ Nickel content of nickel sulfate ($NiSO_4 \sim 6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.
11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.
12/ Include nickel sulfate plus exported metal in concentrate.
13/ Data represent production from domestic nickel ore.
14/ Previously published as "Other, metal." Data represent production from imported Botswanan matte and South African nickel sulfate.
15/ See "Zimbabwe, metal, toll refined from imported materials."

TABLE 12
NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1996	1997	1998	1999	2000
Matte:					
Australia 3/	28,768	37,010	47,459	28,190	41,771
Botswana	22,095 r/	20,157	22,851	22,898 r/	24,218
Brazil 4/	--	1,180	4,670	9,306	8,475 p/
Canada e/ 5/	50,000	45,000	48,000 r/	52,000	37,000
Indonesia	49,000	33,654	35,697	45,400 r/	59,200
New Caledonia	11,239	10,580	12,011	11,353	13,549
Russia e/ 6/	320	366	98	114 r/	480
Total	161,000 r/	148,000	171,000 r/	169,000 r/	185,000
Other:					
Cuba: 7/					
Sulfide precipitate	24,066 r/	24,507 r/	25,176 r/	24,999 r/	27,288
Ammoniacal liquor precipitate	425	803	1,385	1,119	1,125
Total	24,491	25,310	26,561	26,118	28,413

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ Table includes data available through July 27, 2001. Data represent nickel content of matte and other intermediate materials produced for export.
2/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
3/ Total matte production on a contained nickel basis, in metric tons, was as follows: 1996--74,000; 1997--85,800; 1998--100,071 (revised); 1999--79,668 (revised); and 2000--103,000.
4/ The Fortaleza smelter was commissioned in December 1997. All output is being shipped to Finland for further processing.
5/ Estimated nickel content of reported exports.
6/ Export figures reported by importing countries: primarily France and Norway. Exports to Norway were estimated to have a nickel content of 40%.
7/ Corrected for coproduct cobalt.

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FIGURE 1
NICKEL: LONDON METAL EXCHANGE CASH PRICE AND STOCKS

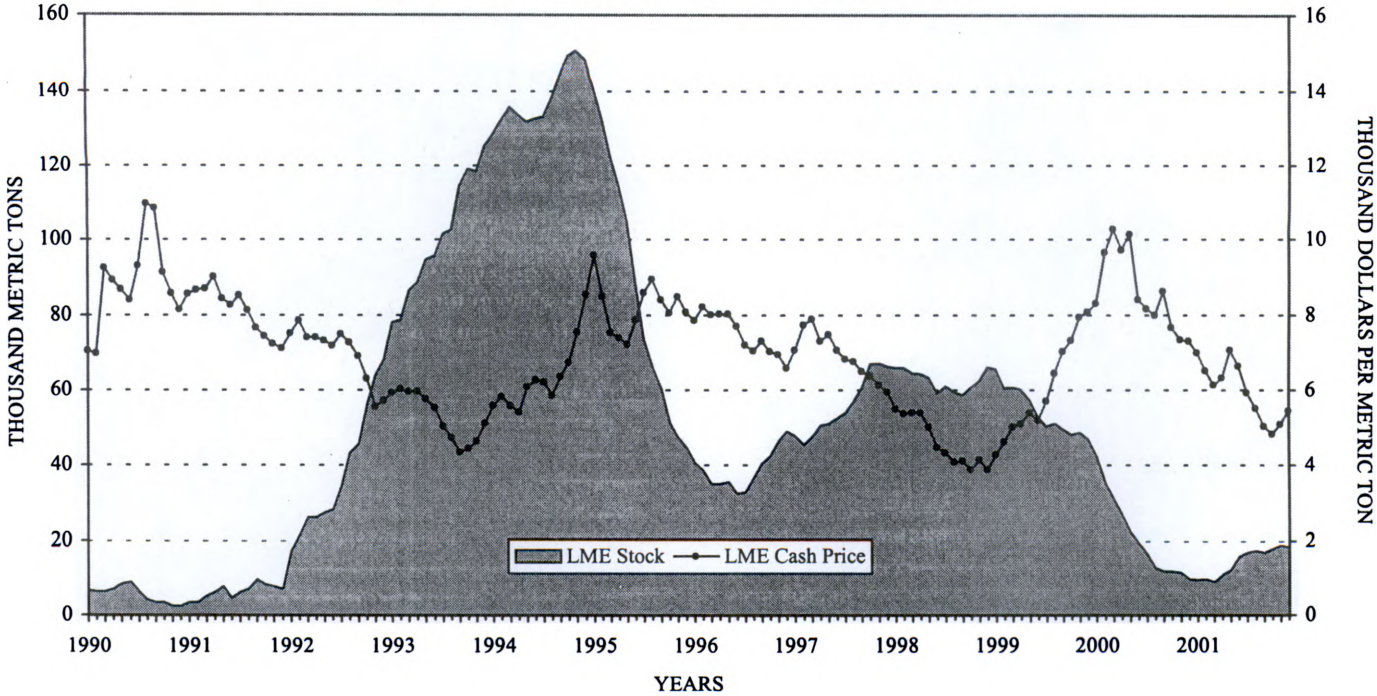
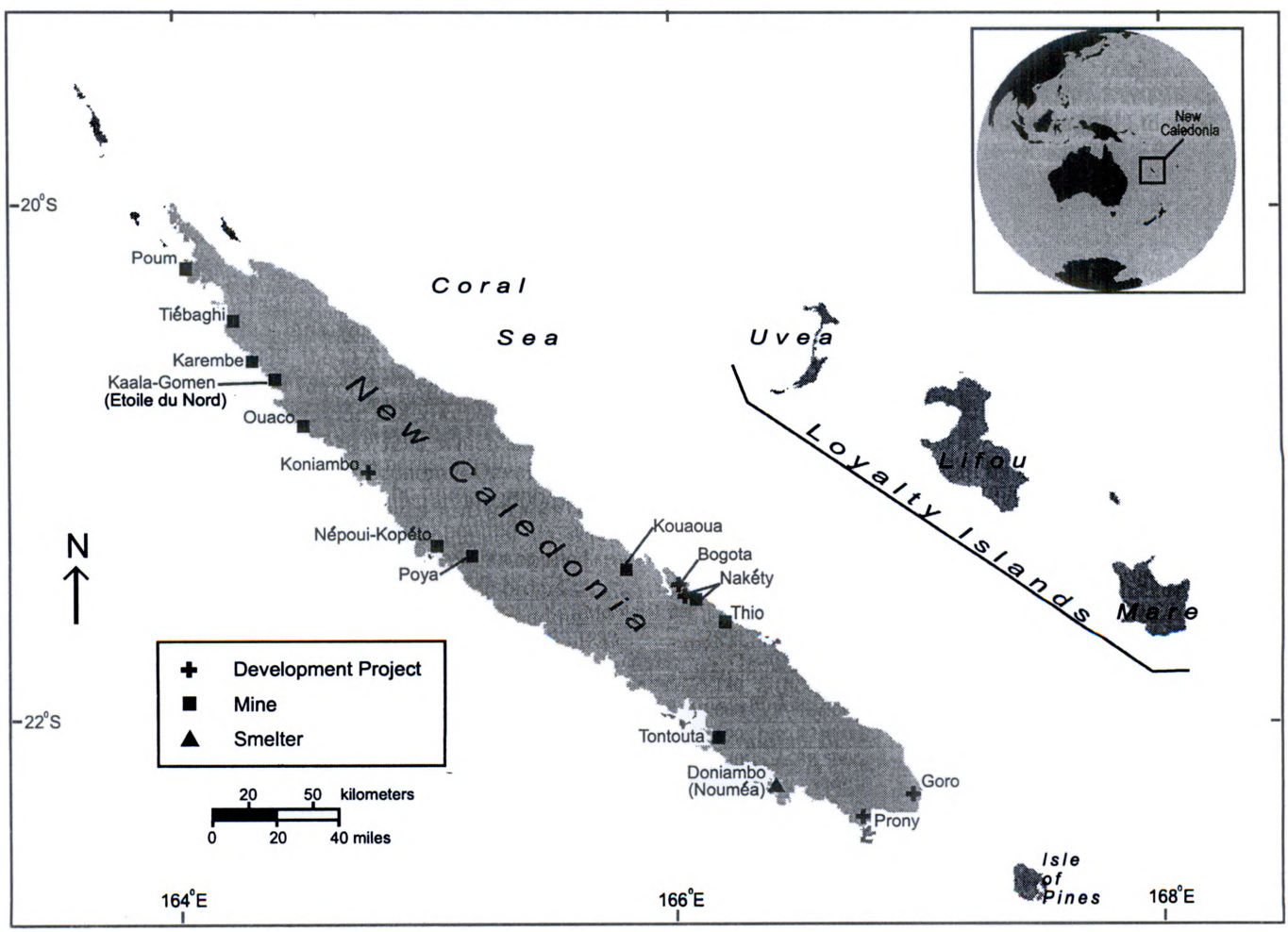


FIGURE 2
NICKEL: OPERATIONS AND PROJECTS IN NEW CALEDONIA



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NITROGEN

By Deborah A. Kramer

Domestic survey data and tables were prepared by Feri Naghdi, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Nitrogen (N) is an essential element of life and a part of all plant and animal proteins. As a part pf the DNA and RNA molecules, N is an essential constituent of each individual's genetic blueprint. As an essential element in the chlorophyll molecule, N is vital to a plant's ability to photosynthesize. Some crop plants, such as alfalfa, soybeans, garden peas, and peanuts, can convert atmospheric nitrogen into a usable form in a process called fixation. Most nitrogen available for crop production, however, comes from decomposing animal and plant waste or from commercially produced fertilizers.

All commercial fertilizers contain their nitrogen in the ammonium and/or nitrate form or in a form that is quickly converted to these forms once the fertilizer is applied to the soil. Commercial production of anhydrous ammonia is based on reacting nitrogen with hydrogen under high temperatures and pressures. The source of nitrogen is air, which is almost 80% nitrogen. Hydrogen is derived from a variety of raw materials, including water and crude oil, coal, or natural gas hydrocarbons. Other nitrogen fertilizers are produced from ammonia feedstocks through a variety of chemical processes. Small quantities of nitrates are produced from mineral resources principally in Bolivia and Chile.

In 2000, U.S. ammonia production was 12.3 million metric tons (Mt) of contained N, a 5% decline from that in 1999. Although the United States produced most of its ammonia requirements, imports, mainly from Canada, Russia, and Trinidad and Tobago, supplied a portion of consumption. Apparent consumption of ammonia also decreased by 5%. About 88% of the ammonia was used in fertilizer applications.

By yearend, the skyrocketing price of natural gas in the United States resulted in the temporary closure of significant quantities of ammonia production capacity. At the end of 2000, about 5.6 Mt of annual capacity was closed (including permanent facility closures). The closure of this ammonia capacity led to closures at urea and urea ammonium nitrate solution (UAN) plants because of the lack of ammonia feedstock. Several producers were selling their natural gas futures instead of producing ammonia. Two ammonia facilities—one in Louisiana and one in Oklahoma—were permanently closed during the year, and a new plant that uses petroleum coke as a feedstock opened in Kansas.

Global ammonia production in 2000 increased by about 2% from that of 1999 to about 109 Mt of contained N. China, India, and the United States continued to be the principal producers. In 2000, world urea production increased slightly to 49.4 Mt of contained N. Urea exports increased by nearly 9% to 12.0 Mt of contained N. China and India, the two largest producing countries, accounted for 47% of world production; production in China increased by about 2% and production in India decreased by 1% compared with those of 1999. The

Ammonia in the 20th Century

Prior to the 20th century, sources of fixed nitrogen compounds were limited to natural organic materials, natural nitrates, and coke-oven byproducts. By 1910, two techniques for nitrogen fixation were commercially established but required significant quantities of energy. During the first decade of the 20th century, the worldwide demand for nitrogen-based fertilizers exceeded the existing supply. The largest source of nitrogen was found in a huge guano deposit (essentially sea bird droppings) that was 350 kilometers in length and 1.5 meters thick and was located along the coast of Chile. This natural source of ammonia and nitrogenous compounds, however, was disappearing quickly. Fritz Haber invented a large-scale catalytic synthesis of ammonia from elemental hydrogen and nitrogen gas, reactants that are abundant and inexpensive. The original laboratory-scale process was first demonstrated in 1909 and patented by Haber in 1910. Carl Bosch and Friedrich Bergius contributed the invention and development of chemical high-pressure methods of ammonia production, which allowed higher ammonia yields. [These advances in ammonia production methods were the basis for two Nobel Prizes in chemistry—Haber in 1918 and Bergius and Bosch in 1931.] Although the original process has been modified since its development, mostly to improve processing efficiencies, the Haber-Bosch process remained the basis of ammonia production facilities through the end of the 20th century. With the advent of inexpensive ammonia production, consumption of ammonia increased rapidly. Statistical data for ammonia were not available before 1942, but U.S. consumption was estimated to be about 400,000 metric tons per year in the 1940s, with 80% of that used for agriculture. During World War II, demand for ammonia escalated because of the need for ammonium-base munitions. After the end of the war, ammonia demand continued to increase because additional fertilizer was required to grow food for a growing population.

By 2000, the United States, China, and India had become the three largest producers of ammonia in the world. Of a total world production of 109 million metric tons nitrogen content, these three countries produced nearly one-half; U.S. production was about 13 million tons of nitrogen content. The principal use for ammonia remained as a fertilizer, which accounted for about 88% of the total ammonia consumption in the United States. A significant quantity of ammonia was used to produce a variety of downstream products that included urea, ammonium nitrate, ammonium sulfate, and nitric acid, which also were used mainly as fertilizers.

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United States and Canada produced about 11% of the total. China continued its ban on imports of urea and supplied its needs with domestic production. With the passage of the U.S.-China Relations Act of 2000 (Public Law 106-286) and the pending membership of China in the World Trade Organization (WTO), this ban may be lifted.

Legislation and Government Programs

In October, the U.S.-China Relations Act of 2000 was enacted into law. As part of its provisions, the law normalized trade relations with China, ending the annual congressional review of China's normal-trade-relations (NTR) status, and stated that the United States should ask the WTO to monitor China's performance annually as part of China's admission to the organization (CBS News, October 10, 2000, Clinton inks China trade bill, accessed May 23, 2001, at URL http://www.cbsnews.com/now/story/0,1597,234529-412,00.shtml). As a result of granting permanent NTR status to China, the fertilizer industry can benefit from a U.S.-China market access agreement that was signed in 1999. Under the agreement, a tariff rate quota for urea and diammonium phosphate (DAP) would be established, and the importation of a certain quantity of urea and DAP through China's private sector would be allowed. The agreement set tonnage quantities that would be subject to an in-quota tariff rate of 4%. Any imported tonnage above this number would be subject to a 50% tariff rate unless the Chinese Government chooses to waive applying the higher rate. For DAP, the in-quota tonnage would begin with 5.4 Mt and increase to 6.9 Mt by the sixth year. For urea, the in-quota tonnage would start at 1.3 Mt and increase to 3.3 Mt in the sixth year (Green Markets, 2000b).

On October 13, the Committee for Fair Ammonium Nitrate Trade filed a petition with the U.S. International Trade Commission (ITC) alleging that ammonium nitrate from Ukraine was being sold in the United States at less than fair value. As a result, the ITC began an antidumping investigation of imports of ammonium nitrate from Ukraine and determined that there was a reasonable indication that the domestic industry was being injured (U.S. International Trade Commission, 2000). The International Trade Administration (ITA), U.S. Department of Commerce, began its investigation into the antidumping allegation in November and made a preliminary determination in March 2001. According to the ITA's investigation, the estimated dumping margin for J.S.C. "Concern" Stirol was 113.38% ad valorem. The Ukraine-wide rate, which was applicable to all other producers and exporters, was also 113.38%. The ITA also determined that critical circumstances existed. A final determination was set to be completed 105 days after the notice was published in the Federal Register (U.S. Department of Commerce, 2001).

In July, the U.S. Environmental Protection Agency (EPA) established a final rule on how and when States must move to limit nutrient levels and pollution in water bodies. According to the EPA rule, States, territories, and authorized tribes would be required to develop more comprehensive lists of all water bodies that do not attain and maintain water-quality standards. They also would need to establish all necessary total maximum daily loads (TMDLs) over a 10-year period, with an allowance for another 5 years where necessary. The rule also specified elements of approvable TMDLs, including implementation plans containing lists of actions and expeditious schedules to reduce pollutant loadings. The rule established specific timeframes under which the EPA would ensure that lists of waters and TMDLs are completed as scheduled and necessary National Pollutant Discharge Elimination System (NPDES) permits are issued to implement TMDLs. The final rule explained the EPA's discretionary authority to object to and reissue, if necessary, State-issued NPDES permits that have been administratively continued after expiration where there is a need for a change in the conditions of the permit to be consistent with water-quality standards and established and approved TMDLs (U.S. Environmental Protection Agency, 2000).

In June, the Governors of Maryland, Virginia, and Pennsylvania, the Mayor of Washington, DC, and the Administrator of the EPA signed the new Chesapeake Bay Agreement, which established regional standards for Bay restoration over the next 10 years. Included in these standards is a cap on nitrogen and phosphorus loading, which would remain at the existing level of 40% (Governor's Office of the State of Maryland, June 28, 2000, Governor Glendening, leaders from neighboring States sign historic agreement to preserve Chesapeake Bay, accessed June 11, 2001, at URL http://www.gov.state.md.us/gov/press/2000/jun/html/chesbao.html).

Production

Industry statistics for anhydrous ammonia and derivative products were developed by the U.S. Census Bureau. A summary of the production of principal inorganic fertilizers by quarter was reported in the series MQ325B, and industrial gases (including nitrogen) were reported in the quarterly report MQ325C. Final data for inorganic fertilizers were subsequently published in the companion annual report MA325B, and data for industrial gases were published in the annual report MA325C.

In 2000, production of anhydrous ammonia (82.2% N) decreased by 5% to 12.3 Mt of contained N compared with a revised figure of 12.9 Mt in 1999 (table 1). Of the total production, 88% was for use as a fertilizer; the remaining 12% was used in other chemical and industrial sectors (table 2). Because a significant portion of the ammonia production was estimated, production figures reported by the U.S. Census Bureau were probably high; significant declines in production occurred, especially during the fourth quarter of 2000, because of capacity reductions, which may not have been accounted for in the census figures.

The United States remained the world's second largest producer and consumer of elemental and fixed types of nitrogen following China. In declining order, urea, ammonium nitrate, ammonium phosphates (DAP, monoammonium phosphate, and other ammonium phosphates), nitric acid, and ammonium sulfate were the major downstream products produced from ammonia in the United States. Their combined production was 10.5 Mt of contained N, with urea accounting for about 30% of the production (table 3). Of the urea produced in the United States in 2000, 65% was used for UAN production, 22% was consumed in granular form, 11% was consumed in prill form, and 12% was consumed in feedstock for such other uses as melamine production.

Ammonia producers in the United States operated at about

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70% of design capacity; this percentage includes capacities at plants that operated during any part of 2000. Excluding the plants that permanently closed during 2000, more than 55% of total U.S. ammonia production capacity was concentrated in the States of Louisiana (33%), Oklahoma (13%), and Texas (9%), owing to large indigenous reserves of feedstock natural gas. Farmland Industries Inc., Terra Industries Inc., PCS Nitrogen Inc., Agrium Inc., CF Industries Inc., and Mississippi Chemical Corp., in declining order, accounted for 73% of total U.S. ammonia capacity (table 4).

Skyrocketing natural gas prices in the second half of 2000 led to temporary closures of much of the U.S. nitrogen capacity. By the end of 2000, the Henry Hub spot price for natural gas had reached more than $10 per million British thermal units. Much of this rapid price increase occurred in the last 3 months of the year; at the end of October, the price was about $4.50 per million British thermal unit, and by the end of November, it was $6.50 per million British thermal unit (U.S. Energy Information Administration, February 5, 2001, Natural gas weekly market update, accessed May 14, 2001, via URL http://www.eia.doe.gov). In some instances, it became more profitable for the operating companies to sell their natural gas futures contracts than to produce and sell nitrogen products. By yearend, about one-half of the U.S. nitrogen production capacity was shut down (Green Markets, 2000i). In addition to regular maintenance turnaround closings, companies began closing capacity in June in response to higher natural gas prices.

At yearend, the following U.S. ammonia plants were closed because of market conditions: Agrium—Finley, WA; Coastal Corp.—St. Helen's, OR, and Cheyenne, WY; Farmland—Pollock, LA; Koch Nitrogen Co.—Sterlington, LA; Royster-Clark Inc.—East Dubuque, IL; and Terra Industries—Beaumont, TX. The following ammonia plants were partially closed because of market conditions: Agrium—Borger, TX [135,000 metric tons per year (t/yr)]; CF Industries—Donaldsonville, LA (762,000 t/yr); and PCS Nitrogen—Augusta, GA (195,000 t/yr), Geismar, LA (95,000 t/yr), and Lima, OH (112,000 t/yr). In addition, many associated urea and UAN production plants were closed without sufficient ammonia feedstock (Fertilizer Markets News Update, 2000).

In January, Agrium signed an agreement with Unocal Corp. to purchase its nitrogen-based production and distribution businesses for an estimated $398 million. Because of market concentration concerns, the U.S. Federal Trade Commission (FTC) investigated the purchase. As a result, the FTC required Agrium to divest the Unocal deepwater terminal near Portland, OR, part of its upriver terminal in central Washington (Hedges), which contains urea storage capacity, and the leases on three UAN terminals, including one with deepwater access. These assets were sold to J.R. Simplot Co. (U.S. Federal Trade Commission, September 29, 2000, FTC clears Agrium, Inc.'s acquisition of Unocal, accessed May 14, 2001, via URL http://www.ftc.gov). The acquisition was finalized in October and included an ammonia-urea complex in Kenai, AK; an ammonia complex in Finley (Kennewick), WA, which also produced ammonium nitrate, nitric acid, and UAN solutions; and storage facilities and terminals in Kennewick and West Sacramento, CA (Green Markets, 2000a).

Also in January, Coastal announced that it would be acquired by El Paso Energy Corp. The total value of the transaction was approximately $16 billion, including $6 billion of assumed debt and preferred equity. The merger was not completed until January 2001, after FTC approval. As part of the FTC approval, the company agreed to divest its ownership in five pipeline systems and certain offshore assets. The revenue from these sales was expected to be used to pay down some debt (El Paso Corp., January 29, 2001, El Paso Energy completes merger with Coastal, creating the world's leading natural gas company, accessed May 14, 2001, via URL http://www.epenergy.com). Coastal, through its subsidiaries, owned three ammonia plants in Cheyenne, WY, Freeport, TX, and St. Helens, OR, with a total capacity of 471,000 t/yr; the ammonia and nitrogen fertilizer assets were only a small portion of Coastal's holdings.

Farmland announced that it would sell its Coffeyville, KS, oil refinery but retain ownership of the adjacent ammonia and UAN plants. The company opened its nitrogen complex, which uses petroleum coke as a raw material, in September and was running the operation in a start-up mode for the remainder of the year (Green Markets, 2000d).

In April, Mississippi Chemical announced it had signed a letter of intent to purchase a 227,000-t/yr granular urea production facility in Faustina, LA, from IMC-Agrico Co. No purchase price was disclosed. Mississippi Chemical planned to operate the plant in conjunction with its ammonia/urea complex located approximately 1.6 kilometers (km) away in Donaldsonville, LA. IMC Global Inc., one of the partners in IMC-Agrico, previously had announced plans to exit the urea business and other noncore product lines as part of its restructuring program launched in December 1998. IMC had stopped production of urea at its Faustina facility in the summer of 1999, but the 508,000-t/yr ammonia plant would continue to supply ammonia as a raw material for use in IMC-Agrico's production of concentrated phosphate products at the same location (Green Markets, 2000g).

Two separate explosions idled parts of two plants for nearly one-half of 2000. On May 24, an explosion at CF Industries' Donaldsonville, LA, ammonia plant killed two workers and hospitalized nine others (ABC News, May 25, 2000, Plant explosion, accessed May 25, 2000, at URL http://abcnews.go.com/sections/us/DailyNews/ammoniaplant000525.html). Because of this, the company's #3 unit was closed for the remainder of 2000, and portions of other units also were closed for most of the remainder of the year because of collateral damage. A July 14 explosion in the ammonia unit at Farmland's Lawrence, KS, ammonia-UAN complex that caused minor damage shut down the plant for a short period. Because of the fire, the company performed a complete turnaround on the plant, and it was brought back on-stream in November (Green Markets, 2000c).

Willard Grain & Feed Inc., operating as Wil-Grow Fertilizer Co., announced that it would liquidate all of the company assets and cease business in February. The company operated ammonia, ammonium nitrate, and UAN production facilities at Pryor, OK; these facilities had been idle since the end of 1999 (Green Markets, 2000k).

In June, Borden Chemical & Plastics L.P. announced that it would close and scrap its ammonia and granular urea complex in Geismar, LA. The company cited a decline in nitrogen values and increasing cost of natural gas feedstock as part of its reason to close the operation (Fertilizer Markets, 2000b).

LaRoche Industries Inc. filed for chapter 11 bankruptcy in May. At the time of the filing, LaRoche estimated that it had more than 1,000 creditors, with Cytec Industries Inc., its equal partner in the Avondale Ammonia Co. joint venture, as the

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fourth largest. In August, LaRoche announced the sale of its ammonium nitrate facilities in Alabama, Missouri, Illinois, and Utah to Orica LLC, a unit of Orica Ltd., an international manufacturer and distributor of explosives. After the U.S. Bankruptcy Court in Delaware approved the sales, Orica then sold the Cherokee, AL, and Crystal City, MO, facilities to LSB Industries Inc., which planned to operate these facilities under its El Dorado Chemical Co. subsidiary; these facilities included a 159,000-t/yr ammonia plant in Cherokee (Green Markets, 2000f). In April 2001, the Court approved LaRoche's settlement with Cytec in which Cytec will take over total ownership of the Avondale Ammonia plant for $800,000 (Green Markets, 2001).

Environment

The ammonium and nitrate forms of N are highly soluble in water and are readily available for crop plant uptake. Ammonium is held by soil particles and, therefore, is not subject to movement down through the soil during periods of rainfall or irrigation. Nitrates, however, do move downward with soil water. This leaching process can lead to nitrate accumulation in ground water. As soils are warmed during the growing season, the ammonium form of nitrogen is subject to conversion to nitrate in a process called nitrification. Most of the ammonium not used by the crop is eventually converted to nitrate. Nitrogen stabilizers and nitrification inhibitors can slow the conversion of soil ammonium to nitrate. Best management practices to increase nitrogen use efficiency and to reduce nitrate leaching include application of fertilizer close to the time of actual crop use, multiple applications, terracing, grass waterways, and strip cropping.

Hypoxia in the Gulf of Mexico recently has become a controversial environmental concern for the fertilizer industry and an issue that spawned significant research efforts to determine its cause. "Hypoxia in the Gulf of Mexico" refers to an area along the Louisiana-Texas coast in which water near the bottom of the gulf contains less than 2 parts per million of dissolved oxygen. Hypoxia can cause stress or death in bottom-dwelling organisms that cannot move out of the hypoxic zone. Some studies postulated that nitrate runoff from fertilizers is the principal cause of hypoxia, while others cited other causes for the hypoxic zone.

U.S. Geological Survey (USGS) study results published in 2000 supported previous findings that most of the nitrogen pollution delivered to the Gulf of Mexico by the Mississippi River originates far upstream in the upper Midwest and Ohio Valley States. But this study also found that within these regions there were large differences in the percentage of nitrogen reaching the gulf, depending on the relation of the location of nitrogen sources to streams of different sizes in the watershed. The study found that the rates of nitrogen reaching the gulf from upstream areas near large rivers in such States as Ohio and Minnesota were much higher than those in neighboring areas near small streams. Moreover, areas near large rivers in these same States, located more than 2,400 km from the gulf, also deliver more nitrogen to the Gulf than areas near small streams in the states of Mississippi and Arkansas, located only a few hundred kilometers from the Gulf. This study found that nitrogen pollution was naturally removed from water much more rapidly in small streams than in large rivers. As a result, nitrogen delivery from point and nonpoint sources in a stream drainage basin was not simply a function of the distance between the gulf and the nitrogen source, but a function of the amount of time the nitrogen traveled through small streams (U.S. Geological Survey, 2000, Percentage of stream nitrogen reaching the Gulf of Mexico, accessed May 15, 2001, at URL http://www.usgs.gov/themes/nature.html). The data supporting these conclusions also has been published as a map. Information on additional USGS involvement in hypoxia research is available at URL http://toxics.usgs.gov/highlights/hypoxia.html.

A group of scientists from Federal agencies and academic institutions completed its report "Hypoxia in the Northern Gulf of Mexico," which was released in May 2000. In this assessment, a national model of the agriculture sector was used to examine many of the economic effects and the changes in nitrogen loading under various scenarios. Reducing nitrogen loss at the edge of the field by 20% through a combination of economically optimal improvements in farming practices would be expected to cost producers and consumers about $0.40 per pound of nitrogen reduction. Other measures to reduce nitrogen loads to rivers and streams, such as reducing urban point and nonpoint sources and atmospheric deposition, could provide important contributions in some instances; average costs of reducing point sources and atmospheric deposition were estimated to be between $5 and $50 per pound. Increasing the acreage of wetlands and vegetated riparian buffers within the basin would enhance denitrification (a process that removes nitrogen from the system), increase nitrogen retention, and decrease the amount of nitrogen entering streams and rivers. Model analyses demonstrated that the most effective use of restored and created wetlands would be in watersheds that discharge high quantities of nitrogen. At typical denitrification rates for flow-through wetlands, more than 2 million hectares of wetlands would reduce nitrogen load to the gulf by 20% and would cost an estimated $4.05 per pound of nitrogen denitrified. An estimated 7.7 million hectares of additional riparian buffers would be needed to reduce nitrogen load to the gulf by the same amount (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, May 2000, Hypoxia in the northern Gulf of Mexico, accessed November 7, 2000, at URL http://www.nos.noaa.gov/products/pubs_hypox.html).

On October 11, Federal and State officials agreed on a $1 billion per year plan to revive as much as 30% of the hypoxic zone in the Gulf of Mexico by 2015. Under the plan, more money would go to programs that reduce excess nutrients in streams and rivers feeding into the Mississippi, which drains 40% of the continental United States. These programs would cut fertilizer use on farms, establish wetlands and buffer strips near streams to soak up excess nitrogen, and reduce discharges from sewage treatment plants. The plan also called for funding scientific efforts to track the flow of nitrogen (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, October 12, 2000, Agreement to shrink dead zone, accessed May 17, 2001, at URL http://www.nos.noaa.gov/products/pubs_hypox.html#update).

A report prepared by the National Research Council of the National Academy of Sciences stated that the Federal Government—along with State and local agencies—should develop a comprehensive regulatory solution to combat nitrogen and phosphorous runoff from agricultural fields, which was causing serious environmental damage along the Atlantic and Pacific coastlines. The committee that prepared the reports said

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that a national strategy should strive to reduce the number of severely damaged coastal areas by 25% by 2020 and to ensure that no other areas become affected. Initiatives that were identified by the committee to address the problem included expanding monitoring and assessment programs, exerting Federal leadership on issues spanning multiple jurisdictions or threatening federally protected natural resources, eliminating overlap and gaps among existing and proposed Federal legislation, providing data and technical assistance to local coastal authorities, and developing a classification scheme to provide better information on the likelihood that excess nutrients will damage coastal areas (Green Markets, 2000h).

Nutrient runoff also was hypothesized to cause deterioration of the coral reefs in the Florida Keys. According to a report prepared by scientists from the University of Miami, nutrients in runoff from the Everglades agricultural area were generating algal blooms, which in turn have killed sponges, increased turbidity, reduced the light available to seagrasses, and altered the entire food web of Florida Bay. The research also has shown that this nutrient- and algae-rich water was transported into the Florida Keys coral reef tract, where water quality has declined (Larry Brand, 2000, An evaluation of the scientific basis for "restoring" Florida Bay by increasing freshwater runoff from the Everglades, accessed May 17, 2001, via URL http://www.reefrelief.org/main.html).

Economic and environmental effects of alternative environmental policies were analyzed using the U.S. Regional Agricultural Sector Model developed by the U.S. Department of Agriculture's (USDA) Economic Research Service. The analysis covered policy effects on most major agricultural commodities. A goal of 10% reduction in nitrogen releases from agriculture was used to illustrate the effects of a small change in nitrogen releases on production and trade. To reduce nitrogen releases by 10%, four alternative generic policy approaches were evaluated: (1) a "green payment" that producers would receive from the Government to compensate for lower returns resulting from lower crop yields caused by reduced fertilizer use; (2) regulations to reduce per-acre nitrogen use; (3) a tax on nitrogen fertilizer; and (4) buffer strips and other land retirement to intercept field runoff and reduce nitrogen fertilizer use. Among the first three policies, a green payment policy would achieve the environmental goal with the least market-price escalation. A green payment approach also would generate the smallest consumer costs and the greatest producer benefits, but it also would involve the greatest Government cost and would result in the largest increase in soil erosion. In contrast, a land retirement policy to achieve the same nitrogen loss reduction would have export-reducing effects almost six times that of a green payment policy, with the largest costs to consumers. Producer benefits in the land retirement scenario were second only to green payments, and the reduction in soil erosion was the greatest of any scenario. (Agricultural Outlook, 2000).

Consumption

In 2000, apparent consumption of ammonia decreased by 5% to 15.4 Mt of contained N. Apparent consumption is calculated as the production plus imports minus exports, adjusted to reflect any changes in stocks.

Consumption of nitrogen fertilizers in the United States for the 2000 crop year (ending June 30, 2000) is listed in table 5. Consumption of 11.2 Mt of contained N was about 2% less than that in 1999. Anhydrous ammonia was the principal fertilizer product, representing 30% of fertilizer consumption. Of the single-nutrient fertilizers, only consumption of urea and ammonium sulfates increased from that in the 1999 crop year.

Other uses of ammonia are in the production of amines, cyanides, and methyl methacrylate polymers (plexiglass); in liquid household and industrial cleaners; in industrial stack-gas scrubbing; in pulp and paper products; in industrial refrigeration; in metallurgy; and as a propellant in vehicular air bags (Nitrogen & Methanol, 2000b).

Urea and UAN solutions constituted 42% of fertilizer consumption during the 2000 crop season. Urea is typically 45.9% N, and UAN solutions are typically 29.8% to 29.9% N. In the industrial sector, urea is used extensively as a protein supplement in ruminant animal feeds, in the production of urea-formaldehyde adhesives, and in the synthesis of plastics and resins.

Ammonium nitrate was used primarily in solid and liquid fertilizers, in industrial explosives, and as blasting agents. After World War II, ammonium nitrate became the leading solid nitrogen fertilizer in the United States and worldwide and remained so until about 1975 when its use was surpassed by synthetic urea. Ammonium nitrate containing 33.9% N constituted 5% of 2000 nitrogen fertilizer consumption.

Ammonium sulfate was used mostly as a fertilizer material, valued for its nitrogen content (21.2% N) and its readily available sulfur content (24.3% sulfur). It is commonly produced as a byproduct of caprolactam production, an intermediate in nylon manufacture. Since the introduction of ammonium nitrate and urea as fertilizer materials, the relative importance of ammonium sulfate worldwide has steadily decreased. In the 2000 crop year, fertilizer consumption of ammonium sulfate, based on nitrogen content, was 2% of the total nitrogen-based fertilizer market. Nonfertilizer uses of ammonium sulfate include food processing, fire control, tanning, and cattle feed.

Nitric acid production is listed in table 3. Nitric acid is used in salt formation reactions to produce metal nitrates and in metal degreasing, treating, and pickling for the graphic and galvanic industries. Nitration reactions with benzene, phenol, and toluene produce dyestuffs, pharmaceutical products, trinitrotoluene explosives, and disinfectants. Esterification reactions with glycol, glycerol, and cellulose produce nitroglycerine explosives (dynamite), celluloid, and nitrocellulose lacquers. Oxidation reactions with toluene, p-xylene, and cyclohexanone produce polyurethanes and polyester fibers (nylon).

Elemental nitrogen is used extensively by the electronics, metals, food, and aerospace industries because of its inert and cryogenic properties. Nitrogen can be used to prevent fires and explosions, as a purging agent for cleaning and processing equipment, and as a controlling atmosphere for annealing and heat treating and other metal preparation processes where oxygenation is a concern.

Stocks

Stocks of ammonia in 2000 were 1.12 Mt, an increase of 12% from those at the end of 1999, according to data published by The Fertilizer Institute (table 6). The U.S. Census Bureau reported ending stocks of ammonia to be 420,000 metric tons

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(t), which was a significant difference from The Fertilizer Institute data. In addition, there were no reported census data for 1999 with which to compare this figure because the 1999 data were withheld. Although the USGS traditionally has used census data in calculating apparent consumption, the calculation was computed using The Fertilizer Institute data to minimize irregularities caused by continually switching data series.

Transportation

Ammonia was transported by refrigerated barge, rail, pipeline, and truck. Three companies serve 11 States with 4,900 km of pipelines, with 4,800 km of river barge transport, and by rail and truck used primarily for interstate or local delivery.

Koch Industries Inc. operated the Gulf-Central ammonia pipeline from the Gulf of Mexico (Louisiana) to the Midwest as far north as Iowa, spanning 3,070 km, and to the east to Huntington, OH. The annual capacity of this pipeline was about 2 Mt, with a storage capacity of more than 1 Mt.

CF Industries and Cargill Fertilizer Inc. jointly operated the 135-km long Tampa Bay pipeline (TBP) system. TBP moved nitrogen compounds and ammonium phosphate for fertilizer producers in Hillsborough and Polk Counties, FL.

The pipelines of Williams Companies Inc. and its subsidiary Mid-America Pipeline System extend from Borger in northern Texas to Mankato in southern Minnesota, covering 1,700 km. The pipelines have an annual capacity of more than 1 Mt and about 500,000 t of ammonia storage capacity. In 2000, Williams formed a wholly owned subsidiary, Williams Energy Partners L.P., to acquire, own, and operate a diversified portfolio of energy assets. This partnership includes Williams' ammonia pipeline and distribution facilities. In October, Williams Energy Partners filed with the Securities and Exchange Commission to register for an initial public offering of stock, which was begun in February 2001 (The Williams Companies Inc., October 30, 2000, Williams Energy Partners L.P. files S-1, accessed November 8, 2000, at URL http://www.williams.com/news/newsreleases/rel618.html).

Capacities for trucks and railcars are usually 20 t and 100 t, respectively. Depending on the product loaded and the volume of the container, barges can accommodate from 400 t to 2,000 t.

Ammonium nitrate is transported by rail, road, and water, but its transportation on U.S. navigable waterways is restricted. Urea is shipped either in bulk or as bagged material.

Prices

Although the individual price curves were slightly different, all the nitrogen prices (ammonia, ammonium nitrate, ammonium sulfate, and urea) reached their highest price of the year at yearend (table 7). Ammonia prices climbed throughout most of the year (figure 1). After a steep climb during the spring planting season to $176 per short ton from $117 per short ton, the price stabilized, then reacted to the escalation in natural gas prices to increase to $230 per short ton by yearend. Granular urea prices rose early in the year to $148 per short ton from $110 per short ton (figure 2), then dropped slightly. After a price spike at midyear, the price leveled off until the very end of 2000 when it, too, reacted to the increased natural gas price. At yearend, the granular urea price was $160 per short ton. The average granular Gulf Coast urea price for the year was about $143 per short ton, more than 50% higher than the 1999 average price. The average ammonia price was $169 per short ton.

Ammonium nitrate prices (figure 3) showed a similar trend to that of urea, rising early in the year, declining, rising again at midyear, then leveling off until the very end of 2000 when they reached their high for the year at $145 per short ton. Ammonium sulfate prices also rose at the beginning of 2000, leveled off at about $122 per short ton, then rose to reach $133 per short ton at yearend (figure 4).

Foreign Trade

Ammonia exports increased by about 18% from those in 1999 (table 8); much of this increase was reflected in increased exports to the Republic of Korea, which remained the principal destination, accounting for 80% of total U.S. exports of ammonia. Most of the material shipped to the Republic of Korea was produced at the Agrium plant in Alaska.

Imports of anhydrous ammonia were essentially the same as those in 1999 (table 9). Trinidad and Tobago (51%), Canada (22%), and Russia (19%) were the primary sources. Tables 10 and 11 list trade of other nitrogen materials and include information on principal source or destination countries.

World Review

Anhydrous ammonia and other nitrogen materials were produced in more than 80 countries. Global ammonia production in 2000 increased by about 2% from that of 1999 (table 12). In 2000, total ammonia production was 109 Mt contained N, according to data reported to the USGS. China, with 26% of this total, was the largest world producer of ammonia. Asia contributed 44% of total world ammonia production, and the United States and Canada represented 15% of the global total. Countries in the former U.S.S.R. produced 13% of the total; Western Europe, 10%; the Middle East, 7%; Latin America, 5%; and Africa, Eastern Europe, and Oceania contributed the remaining 6%.

In 2000, world ammonia exports increased by 6% to 12.7 Mt of contained N compared with those of 1999. Russia (19%), Trinidad and Tobago (19%), Ukraine (10%), and Canada (7%) accounted for 55% of the world total. The United States imported 33% of global ammonia trade, followed by Western Europe (27%) and Asia (20%) (International Fertilizer Industry Association, 2001a, p. 1-11).

In 2000, world urea production increased slightly to 49.4 Mt of contained N. Urea exports increased by nearly 9% to 12.0 Mt of contained N. China and India, the two largest producing countries, accounted for 47% of world production; production in China increased by about 2% and production in India decreased by 1% compared with those of 1999. The United States and Canada produced about 11% of the total. Exports from most geographic areas increased, with the exception of an 8% decrease from North America and a 27% decrease from Latin America. The Middle East exported the largest quantity of urea with 26% of the total. Russia and Ukraine together also accounted for 26% of total exports, Asia for 13%, Canada and the United States for 10%, Western Europe for 8%, Eastern Europe for 7%, and China and Latin America for 4% each. Latin America accounted for 21% of global urea imports, Western Europe for 18%, North America for 17%, and Asia for 16% (International Fertilizer Industry Association, 2001b, p. 1-

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14).

Algeria.—ASMIDAL Group, its trading partner Transammonia Inc., and the German engineering firm Ferrostaal AG signed a memorandum of understanding (MOU) to build a 600,000-t/yr joint-venture ammonia plant. The new facility was expected to be sited in Arzew near two existing ammonia units with a combined capacity of about 550,000 t/yr. Estimated project cost was $370 million, and the product would likely be exported to nearby fertilizer and caprolactam producers on the Spanish Mediterranean coast. The joint-venture partners did not disclose how the equity would be divided or the potential timetable for plant construction (Fertilizer Week, 2000a).

Argentina.— In May, Profertil S.A., the joint venture between Agrium and Repsol YPF S.A., began ammonia trials at its new 1.1-million-metric-ton-per-year (Mt/yr) ammonia-urea complex in Bahia Blanca. A fire at the ammonia plant in July delayed full commissioning of the ammonia section until October, which in turn delayed the start-up of the urea section. The commissioning of the granular urea section, originally scheduled for the second half of 2000, was delayed further because of ammonia leaks and vents that occurred during start-up. By yearend, Profertil decided to install ammonia flare stacks at the complex as protection against future ammonia leaks or vents (Fertilizer Week, 2000v). The urea plant began production in January 2001.

Australia.—Wesfarmers CSBP began commissioning its new $90 million, 650-metric-ton-per-day (t/d) ammonia plant in April. The plant was scheduled to be commissioned in September 1999, but building delays postponed the start-up. The new plant uses Haldor-Topsøe technology and replaced a 300-t/d unit that was closed in August 1999. The additional production from the new plant would also replace ammonia that had been imported from Qatar (Fertilizer Week, 2000c). Wesfarmers used the ammonia as feedstock for ammonium nitrate production, gold extraction, and nickel refining.

Queensland Fertilizer Assets Ltd., Krupp Uhde, a unit of ThyssenKrupp AG of Germany, and Devco International Co. of the United States, signed an MOU to develop a nitrogen fertilizer complex near Pickanjinnie, Queensland. The proposed plant, which was scheduled to be completed by 2003, was expected to have the capacity to produce 330,000 t/yr of ammonia, 330,000 t/yr of urea, and 150,000 t/yr of low-density ammonium nitrate. Krupp Uhde will use its own licensed technology for the production units (Fertilizer Week, 2000z).

Plenty River Corp. and India's Chambal Fertilizers and Chemicals Ltd. terminated the MOU that they signed in 1999 relating to Plenty River's proposed ammonia-urea complex in Western Australia. As part of the MOU, Chambal Fertilizers and Chemicals would be brought into the project as a 50%-equity participant upon completion of a positive feasibility study (Fertilizer Markets, 2000f). Plenty River was seeking a new participant to take Chambal Fertilizers and Chemicals' 50% share. The other equity partners in the project were Snamprogetti S.p.A. of Italy (15%) and Theiss Pty. Ltd. (5%); Plenty River maintains a 30% equity. Right after the MOU was dissolved, Queensland Fertilizer Assets signed a 15-year offtake contract with Helm Düngemittel of Germany GmbH, an international marketing company. Under this agreement, total production of ammonia and urea would be sold to Helm Düngemittel under a 15-year take-or-pay contract. The plant was expected to produce approximately 760,000 t/yr of granular urea with 190,000 t/yr of excess salable ammonia. Construction was scheduled to begin in 2001 with commissioning of the plant in 2004 (Fertilizer Week, 2000u).

Bangladesh.—In May, Bangladesh Chemical Industries Corp. and China's Huanqui Chemical Engineering Co. signed an MOU to conduct a feasibility study for a 560,000-t/yr urea plant in northwestern Bangladesh. Although several sites were under consideration, the most probable site was Sirajganj (Nitrogen & Methanol, 2000a).

Brazil.—After a 3-month shutdown beginning in September, Petróleo Brasileiro S.A. (Petrobras) increased capacity at its ammonia-urea complex in Camacari by about 50%. Total production capacity after the revamp was 495,000 t/yr of ammonia and 500,000 t/yr of urea. Petrobras exported most of its surplus ammonia through a term contract with Transammonia (Fertilizer Week, 2000s).

Bulgaria.—In June, a consortium of a management buyout team and one of its marketing partners purchased 51% of Neochim S.A. for $100,000. After the buyout, the ownership of the plant was shared among the Bulgarian company Evrofert S.A. (the buyout team) (39%), the Lebanese company Karimex Chemicals International S.A. (the marketing partner) (12%), and the Bulgarian Government (24%). Small portions were owned by various funds and private individuals. The new owners planned to invest $5.5 million over 5 years to improve the plant. Production capacity at the plant was estimated to be 410,000 t/yr of ammonia and 630,000 t/yr of ammonium nitrate, but the plant had been operating at only about 40% of the total (Fertilizer Week, 2000o). As part of the buyout, the company reached an agreement with the country's natural gas supplier to extend Neochim's debt repayment period until April 30, 2001.

In November, Bulgaria's Council of Ministers announced an increase in the duty on ammonium nitrate to 40% from 25%; this duty increase was aimed at protecting domestic producers from imports of ammonium nitrate from Georgia, Romania, Russia, and Ukraine. The duty increase was requested by producers in June when gas prices began to climb. The Government started an antidumping duty investigation to parallel the increase in import duties (Fertilizer Week, 2000b.).

Canada.—The sharp increase in natural gas prices that resulted in closures at many U.S. ammonia facilities also had the same effect on many plants in Canada. At yearend, Agrium had closed about 651,000 t/yr of its ammonia capacity in Alberta because of market conditions. This represented about 27% of the company's total production capacity in Alberta (Fertilizer Markets News Update, 2000).

Chile.—After Potash Corp. of Saskatchewan (PCS) purchased the Yumbes nitrate operation in 1999, it renamed the operation PCS Yumbes, and the company began producing nitrates from the deposit in August 2000. The first material to be produced was potassium nitrate. Eventually, the company planned to produce about 300,000 t/yr of nitrates, of which about 265,000 t/yr was expected to be potassium nitrate, and the remaining 35,000 t/yr would be sodium nitrate. For domestic sales, PCS has entered into a marketing agreement with Cargill Inc. to serve Chilean fertilizer and industrial-grade nitrates markets (Fertilizer Week, 2000r).

Sociedad Quimica y Minera de Chile S.A. (SQM) brought its new 160,000-t/yr potassium nitrate plant on-stream at the end of August. As part of the joint-venture agreement that was signed in 1998 between SQM and Norsk Hydro A/S, SQM retained the majority stake in the plant, and by selling nitrates, Norsk Hydro had the opportunity to increase its product range in Europe

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(Fertilizer Week, 2000aa).

A third potassium nitrate plant in Chile was scheduled to begin production by yearend. Compania de Salitre y Yodo S.A. (Cosayach) expected to begin production at its 200,000-t/yr operation near Pozo Almonte. Although potassium nitrate would be the principal product, Cosayach also planned to produce sodium nitrate and iodine (Fertilizer Markets, 2000e).

China.—Yunnan Yuntianhua Co. and its trading partner China National Chemical Construction Co. signed a licensing contract with the Dutch firm Stamicarbon bv to debottleneck and upgrade its urea plant in Shuifu, Yunnan Province. The upgrade was expected to be completed in 2002 and would increase the plant's capacity to about 860,000 t/yr from 535,000 t/yr. In addition to increasing capacity, the revamp was expected to help improve energy consumption (Fertilizer International, 2000c).

China National Offshore Oil Corp. announced that it would construct an ammonia-granular urea plant in Dongfang City, Hainan Province. Proposed plant capacity was 450,000 t/yr of ammonia and 800,000 t/yr of urea. Construction of the $362 million plant was scheduled to begin in 2001, with completion scheduled for 2003 (Fertilizer International, 2000c).

Egypt.—By September, Egyptian Fertilizer Co. completed the start-up of its ammonia-urea complex in Ain Sukhna. The new plant could produce 635,000 t/yr of granular urea and an additional 50,000 t/yr of excess ammonia. Egyptian Fertilizer has long-term contracts for 100,000 t/yr of urea each with four international trading firms and two local firms. Although the material would initially be shipped from existing ports to its principal markets in Israel, Jordan, Mauritius, and South Africa, Egyptian Fertilizer planned to construct a bulk handling terminal by the second quarter of 2001 that would be Egypt's only terminal capable of handling panamax and cape-sized vessels (Fertilizer Week, 2000h).

European Union.—The European Commission (EC) enacted a significant number of antidumping decisions during 2000. In September, the EC established definitive antidumping duties on UAN from Algeria, Belarus, Lithuania, Russia, and Ukraine; these duties will last for 5 years. The duties (in euros per metric ton) were as follows: Algeria, 6.88; Belarus, 17.86; Lithuania, 3.98; Russia, 17.80 to 20.11, depending on the company; and Ukraine, 26.17. The original complaint, filed by the European Fertilizer Manufacturers Association (EFMA) included UAN from Slovakia, but imports from this country were still being investigated (Fertilizer Markets, 2000d).

In July, the EC imposed 6-month provisional antidumping duties on imports of ammonium nitrate from Poland and Ukraine. For Poland, the duty ranged from 22.61 euros per metric ton to 29.91 euros per metric ton, depending on the producer. For Ukraine, the country-wide duty was 33.25 euros per metric ton. The original investigation included imports from Lithuania; however, the EC found the dumping margin from this country to be minimal and did not establish any provisional duties (Fertilizer Week, 2000k).

In September, the EC also began an interim review of current antidumping duties on imports of ammonium nitrate from Russia. The existing duty of 26.3 euros per metric ton expired in August, and EFMA asked for a review in March (Fertilizer Week, 2000j). In October, the EC began an antidumping investigation into imports of urea from Belarus, Bulgaria, Croatia, Egypt, Estonia, Libya, Lithuania, Poland, Romania, and Ukraine. The EFMA lodged a complaint in September alleging that volumes and prices of urea from these countries had a damaging effect on the sales and markets shares of its members (Fertilizer Week, 2000g).

India.—In February, the Indian Government announced a 3-year moratorium on all domestic greenfield urea projects and that it could not guarantee that proposals to expand existing units would be protected under the country's retention pricing scheme (RPS). [The RPS ensured project feasibility by allowing an automatic 12% after-tax return on capital investment as soon as new units are commissioned.] This new policy eliminated proposals for new projects that were recently approved—Indian Farmers Fertiliser Cooperative Ltd.'s (IFFCO) 768,000-t/yr new plant at Nellore, Krishak Bharati Co-operative's (Kribhco) 768,000-t/yr expansions at Hazira and Gorakhpur, and Rashtriya Chemicals & Fertilizers Ltd.'s 726,000-t/yr expansion at its Thal complex (Fertilizer Week, 2000e).

Indonesia.—PT Kaltim Parna Industri, a joint venture between Japanese firms Mitsubishi Corp. (55%) and Asahi Chemical Industry Co. Ltd. (10%) and the Indonesian companies PT Parna Raja (25%) and PT Pupuk Kalimantan Timur (Kaltim) (10%), started construction of a $240 million ammonia plant in Bontang, East Kalimantan. The project, which had been postponed since 1997, was scheduled for completion in 2002. Capacity at the plant was projected to be 495,000 t/yr. Natural gas for the plant will be supplied by the State-owned natural gas company under a 20-year contract. Output from the plant was expected to be exported primarily to China, Japan, the Philippines, and Thailand (Fertilizer Week, 2000n). Kaltim Pasifik Amoniak began production at its 660,000-t/yr ammonia plant in Bontang in March, and its first export sales were completed in April.

PT Pupuk Sriwidjaja, the holding company for Indonesia's State-owned fertilizer producers Kaltim, PT Petrokimia Gresik, PT Pupuk Kujang, and PT Pupuk Iskandar Muda (PIM), delayed three fertilizer projects pending clarification of the Government's privatization plans. The three projects were Kujang's 570,000-t/yr urea plant at Cikampek, Java; Kaltim's 570,000-t/yr urea plant at Bontang, East Kalimantan; and PIM's ammonia-urea complex at Lhokseumawe, Aceh (Fertilizer International, 2000a).

Israel.—Haifa Chemicals Ltd. completed a debottlenecking and expansion project that doubled the company's potassium nitrate production capacity to 100,000 t/yr. Haifa Chemicals marketed the potassium nitrate for agricultural and industrial applications (Fertilizer International, 2000b).

Malaysia.—Production at Petronas Ammonia Sdn. Bhd.'s new 450,000-t/yr ammonia plant at Kerteh began in October. Most of the production was destined for export. Mitsubishi and Mitsui & Co. Ltd. signed MOU's with Petronas for the offtake of the ammonia, but final agreements were not completed by yearend (Fertilizer Week, 2000t).

Mexico.—In May 1999, Agro Nitrogenados de Mexico S.A. de C.V. (Agromex) had stopped production of urea because Petroquimica Cosoleacaque S.A. de C.V. stopped supplying ammonia to the plant when Agromex's parent company filed for bankruptcy. Although press reports indicated that there was an agreement on feedstock supplies among the Energy Ministry, Pemex, and domestic fertilizer producers that would allow the restart of Agromex's 1.1 Mt/yr urea production capacity in February, the agreement fell through (Fertilizer Week, 2000p).

Because of the stoppage in domestic production, imports of

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urea into Mexico increased significantly in the past 2 years. Compared to imports of 340,000 t in 1998, urea imports increased to 495,000 t in 1999 and to 561,000 t in 2000. Much of these imports were supplied by Russia (55% in 2000) (International Fertilizer Industry Association, 2001b, p. 7L-7R). Because of the increased imports from Russia, Agromex had petitioned Mexico's customs agency to investigate dumping of imports from Russia and the United States. The investigation began in 1999, and in April 2000, the authorities determined that Mexican urea production was not harmed by imports of Russian and United States urea. The Government determined that Agromex could not start its urea plants, because the high cost of domestically produced ammonia did not allow domestic urea to compete with cheaper imports. As a result of this determination, Agromex decided to sue the Government claiming that imports improperly lowered urea values. Agromex wanted Mexican authorities to convene a trilateral commission under the auspices of the North American Free Trade Agreement to examine the determination (Fertilizer Markets, 2000a).

Netherlands.—Kemira Agro Oy announced that it would close its nitrogen operations in Rozenberg as part of its restructuring program. The Roenberg operations included capacities of 550,000 t/yr of ammonia and 230,000 t/yr of urea, as well as production capacity of UAN and calcium ammonium nitrate. High natural gas prices and persistent oversupply in the European nitrogen fertilizer markets were cited as additional reasons for closure (Fertilizer Week, 2000m).

Oman.—In June, the Indian Government signed an offtake agreement for the production from the proposed Oman-India Fertilizer Co. ammonia-urea joint venture. Under the terms of the agreement, the Government would honor a 25-year take-or-pay contract for 1.6 Mt/yr of urea from the plant. Any surplus ammonia that would be generated was expected to be taken by IFFCO, one of the joint-venture partners (25%), under a 15-year agreement (Fertilizer Week, 2000d). The new plant was expected to be completed in 2003, with a capacity of 1.67 Mt/yr of granular urea and 1.2 Mt/yr of ammonia. Kribhco (25%) and Oman Oil Co.(50%) were the other partners in the joint venture.

Suhail Bahwan Group announced that it would construct an ammonia-urea complex in the Sohar industrial area. The new plant would have a design capacity of 2,000 t/d of ammonia and 2,600 t/d of granular urea. The estimated cost of the plant was between $450 million and $500 million; 30% of this cost was expected to be funded by Sheikh Suhail Salem Bahwan and the remaining 70% was expected to be financed. Construction was scheduled to begin by mid-2001, after a contractor is selected, and would be completed by 2004 (Fertilizer Week, 2000x).

Pakistan.—In June, Pakistan's Privatisation Commission invited bids for a controlling stake in the country's largest nitrogen fertilizer producer, Pak-Saudi Fertilizers Ltd. The local government expected to sell its majority holding by early 2001. The plant, in Mairpur Mathelo, could produce 557,000 t/yr of urea and 320,000 t/yr of ammonia. This was the second attempt to privatize the plant. Although the deadline to submit bids originally was in October, the committee extended the deadline by 3 months because of a lack of interest from foreign buyers (Nitrogen & Methanol, 2000c).

Engro Pakistan Chemical Ltd. announced that it would add 100,000 t/yr of capacity to its urea plant in Daharki by 2002. This would bring the total capacity at the plant to 950,000 t/yr. The new capacity was being added to provide material for the company's 100,000-t/yr nitrogen-phosphorus-potassium (NPK) granulation unit under construction at Port Qusim in 2001 (Fertilizer Week, 2000i).

Qatar.—Qatar Fertiliser Co. (Qafco) received approval for its Qafco IV expansion in October. The expansion would increase total capacity at the Umm Said complex to 2.8 Mt/yr of urea, making it one of the largest urea plants in the world. The cost of the expansion was estimated to be $500 million, and bids for plant construction were expected to be finalized by the third quarter of 2001. The expansion was scheduled to be on-stream by mid-2004 and primarily would supply the nearby Indian market (Fertilizer Week, 2000y). Qafco is a 75%-25% joint venture between Qatar General Petroleum Corp. and Norsk Hydro.

Russia.—TogliottiAzot, Russia's largest ammonia and urea producer, announced a plan to build an ammonia terminal that would give it direct access to the Black Sea. The company had been exporting its ammonia via a 2,250-km pipeline that runs to the Ukranian port of Yuzhnyy. Because one-third of the pipeline runs through Ukraine, the Russian ammonia had been subject to tariffs ($23 per metric ton) and restrictions on throughput (1.25 Mt/yr). The proposed ammonia terminal would consist of the construction of ammonia handling facilities near Temryuk, on the Russian coast of the Azov Sea, which flows directly into the Black Sea. This terminal could handle large ammonia vessels and panamax-size ships. The project also would involve transporting ammonia by rail 350 km south from a point on the existing pipeline close to the Russia-Ukraine border and include a new 35-km section of rail line. The project was estimated to cost $200 million, some of which would be offset against the cost of the Ukrainian tariffs and some of which may be financed by the European Bank for Reconstruction and Development (Fertilizer International, 2000d).

Saudi Arabia.—The National Chemical Fertilizer Co., a joint venture between Saudi Arabia Basic Industries Co. (Sabic) and Saudi Arabian Fertilizer Co., announced that it would debottleneck its ammonia plant at ibn al-Baytar to increase capacity to 583,000 t/yr from 500,000 t/yr. The expansion, which was to be completed by Japan's Toyo Engineering Corp. by the first quarter of 2002, would supply some of the feed requirements for Sabic's increase in urea production capacity (Fertilizer Week, 2000w).

South Africa.—Norway's Norsk Hydro acquired 51% of Kynoch Fertilizer Ltd. and, as a result, owned the company in a joint-venture agreement with its former parent AECI Ltd. Through the agreement, Kynoch would produce and market NPK and liquid fertilizers in the South African market. As part of the agreement, Norsk Hydro would supply 250,000 t/yr of plant nutrients, and Kynoch would close its nitrate production plants in South Africa (Industrial Minerals, 2000).

Trinidad and Tobago.—On December 31, 1999, PCS shut two of its four ammonia plants in Point Lisas because of a disagreement with its natural gas supplier, National Gas Co. of Trinidad and Tobago Ltd. A 15-year supply contract expired at the end of 1999, and contract terms suitable to both parties were not agreed upon, which resulted in the closure of 930,000 t/yr of capacity. PCS's two other ammonia plants and its urea plant at the same location, however, were not affected. It was not until the middle of June that the two companies negotiated a gas-supply contract and production at the plants restarted (Fertilizer Week, 2000q).

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Construction of the $268 million 645,000-t/yr Caribbean Nitrogen Co. Ltd. ammonia plant in Point Lisas began early in 2000. Ferrostaal is responsible for construction of the facility using technology supplied by M.W. Kellogg Corp. The construction time was estimated to be 28 months, and start-up of the facility was scheduled for the last quarter 2002. Debt financing was expected to be provided by Kreditanstalt für Wiederaufbau backed by the German credit insurance agency Hermes. The shareholders of the project were Clico Energy Co. Ltd., U.S.-based Duke Energy Corp., EOG Resources Trinidad Ltd., KBR Development Corp., and Ferrostaal. Even before this plant is completed, Duke Energy was seeking financing for a second 650,000-t/yr plant at the same location. The $300 million to finance the second plant was expected to come from the same companies that financed the first plant. If financing is completed by early 2001, the new plant could be operational by 2004 (Fertilizer Markets, 2000c).

Turkey.—In June, the Turkish Privatisation Administration announced that it would accept bids for the privatization of fertilizer producers Istanbul Gübre Sanayii (Igsas) and Türkiye Gübre Sanayii (Tügsas). Igsas was the country's sole urea producer with four plants totaling 560,000 t/yr of capacity, and Tügsas produced ammonium nitrate, DAP, and compound fertilizers at a number of plants. Although Toros Fertilizer and Chemical Co.'s bid for two of the Igsas units, its port installations, and its distribution network was accepted by the Privatisation Administration, it was rejected by the country's competition authorities in November. Toros was one of the country's largest urea importers, and it was determined that this purchase would limit competition in the urea market. Bids for the Tügsas plants were rejected by the Privatisation Administration (Fertilizer Week, 2000bb).

Ukraine.—Because of its failure to pay an estimated $21.6 million in taxes since it was founded in 1997, Ukrzovnishkhimprom, which controlled the Togliatti-Yuzhnyy ammonia pipeline, would be broken into independent regional companies. The companies would be subsidiaries of newly formed Ukykhimtransammiak and would charge ammonia shippers for transportation and pay taxes to local authorities (Fertilizer Week, 2000cc). The Government also withdrew approval to nitrogen fertilizer producer DneproAzot to build an ammonia pipeline from its plants in Dneprodzerzhinsk to connect to the Togliatti-Yuzhnyy pipeline. The Government said that the funds for the project, which were to be partially supplied by duties from transporting Russian ammonia, should not be used to support a project promoted by a company that belongs to offshore shareholders (Fertilizer Week, 2000f).

United Arab Emirates.—By October, Southern Petrochemical Industries Corp. was approximately 50% finished with its conversion of an ammonia-urea unit to use natural gas rather than naphtha as a feedstock. Projected start-up of the 400,000-t/yr urea plant in Jebel Ali was late 2001, which is almost 3 years later than originally planned. Prolonged negotiations for gas supply agreements and low urea prices were cited as the reasons for the delay (Nitrogen & Methanol, 2000d).

Venezuela.— Fertilizantes Nitrogenados de Venezuela (FertNitro) completed construction of its ammonia-urea complex in Jose in the fourth quarter. The plant was jointly owned by Petroquimica de Venezuela S.A., Koch Nitrogen, Snamprogetti, and Empresas Polar. After start-up in early 2001, FertiNitro will produce over 1.2 Mt of ammonia and 1.5 Mt of urea annually. Much of the plant's output was expected to be destined for North American markets (Fertilizer Week, 2000l).

Current Research and Technology

The Iowa State University extension developed a web page featuring a soil temperature map for each county and the statistical probability of temperatures over a period of time. The goal of this project was for producers, agricultural businesses, and fertilizer dealers to apply anhydrous ammonia when soil temperatures are 50° F and trending lower; applying ammonia below this temperature reduces nitrate leaching, which leads to lower nitrogen losses. The web site would use soil temperature data from weather stations around Iowa. The observed soil temperature data would be placed on the World Wide Web and used with air temperature readings to compute soil temperatures for counties without actual observations (Green Markets, 2000e).

Perdue-AgriRecycle introduced a new product called MicroStart60™, the brand name for a fertilizer made from pelletized chicken litter. The company was constructing a $10 million facility in Sussex, DE, that, when completed in early 2001, would be able to process 80,000 t/yr of chicken litter. The company contracted with producers on the Delmarva peninsula to provide the raw material. According to Perdue-AgriRecycle, the nutrient content of the pelletized material is 3% nitrogen, 3% phosphorus, 3% potassium, and 60% organic matter. The company also claimed that the product provides micronutrients such as calcium, copper, iron, magnesium, manganese, sulfur, and zinc, and provides water-insoluble nitrogen that is released slowly over a long period of time, which prevents runoff and resultant nutrient loss (Green Markets, 2000j).

Outlook

According to the USDA, farmers' planting intentions for the eight major field crops (corn, soybeans, wheat, barley, sorghum, oats, cotton, and rice) total 101.8 million hectares in the 2000-2001 crop year, a drop of 1.3% from the last year's planted area. Farmers intend to plant a record 31.0 million hectares of soybeans, 3% more than in 2000 and the 10th straight increase. Corn plantings are expected to be down 4%, wheat plantings are expected to be down by 4%, and projected cotton area, 6.3 million hectares, is the largest since 1995. With adverse weather or significant changes in crop prices, actual plantings could vary from intentions. For example, persistent wet conditions this spring could delay corn plantings and cause an even greater switch from corn to soybeans. Higher fertilizer and fuel costs, reflecting the effect of higher natural gas prices, represent another important factor in the expansion of soybean plantings this year, because corn production uses significantly more nitrogen fertilizer relative to soybeans. According to a cost budget prepared by the University of Illinois extension service, nitrogen costs in corn production will increase by $17 per hectare in the 2000-2001 crop year because of higher nitrogen fertilizer prices (Agricultural Outlook, 2001). Based on these planting projections, U.S. nitrogen consumption is expected to decrease in 2001.

In the longer term, the USDA projects that after a decline in planted acres in the beginning of the decade, corn plantings will increase slightly by 2011, projecting a planted acreage of 32.8

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million hectares compared with 31.3 million hectares in 2000 (figure 5). Wheat and soybeans follow a similar pattern, with wheat plantings projected to grow to 26.7 million hectares from 25.4 million hectares, and soybean plantings projected to grow to 30.3 million hectares from 29.8 million hectares (U.S. Department of Agriculture, Economic Research Service, February 2001, Agricultural baseline projections, accessed June 12, 2001, at URL http://www.ers.usda.gov/Briefing/baseline). If these projections are correct, U.S. consumption of nitrogen for fertilizer applications is likely to increase.

If natural gas costs remain high, some U.S. production capacity can be expected to close for extended periods or to shut permanently. The New York Mercantile Exchange Henry Hub natural gas futures contract prices are not projected to increase to much more than $4.00 per million British thermal unit through mid-2004, but these costs are generally higher than they had been before the price spike (New York Mercantile Exchange, [undated], Henry Hub natural gas, accessed June 28, 2001, at http://www.nymex.com/markets/quotes.cfm?showAll=on&contract=NG#NG). High natural gas costs in the United States, coupled with projected ammonia and urea capacity increases in South America, could lead to a higher level of imports. Material from this region potentially could be brought into the United States at a significantly lower cost than U.S.-produced material, which could put further pressure on U.S. ammonia and urea producers to close facilities.

References Cited

Agricultural Outlook, 2000, Curbing nitrogen runoff—Effects on production and trade: Agricultural Outlook, AGO-271, May, p. 19-21.

———2001, Soybean plantings to expand, corn to recede in 2001: Agricultural Outlook, AGO-281, May, p. 5-9.

Fertilizer International, 2000a, Indonesian projects on hold: Fertilizer International, no. 377, July-August, p. 16.

———2000b, KNO_3 expansion nears completion: Fertilizer International, no. 374, January-February, p. 16.

———2000c, Stamicarbon debottlenecking success: Fertilizer International, no. 377, July-August, p. 14.

———2000d, Togliatti seeks Black Sea outlet: Fertilizer International, no. 376, May-June, p. 23.

Fertilizer Markets, 2000a, Agromex wants NAFTA panel to review urea imports: Fertilizer Markets, v. 10, no. 46, June 5, p. 2.

———2000b, Borden to close, scrap nitrogen facilities: Fertilizer Markets, v. 10, no. 50, July 3, p. 2-3.

———2000c, Duke Energy expansion moves ahead on Trinidad: Fertilizer Markets, v. 11, no. 10, October 2, p. 1-2.

———2000d, EC slaps duties on UAN from FSU and Algeria; Fertilizer Markets, v. 11, no. 10, October 2, p. 2.

———2000e, Third potassium nitrate plant begins production in Chile: Fertilizer Markets, v. 11, no. 17, November 13, p. 2.

———2000f, [Untitled]: Fertilizer Markets, v. 11, no. 20, December 4, p. 4.

Fertilizer Markets News Update, 2000, Production changes affecting North American market: Fertilizer Markets News Update, December 12, unpaginated.

Fertilizer Week, 2000a, Asmidal, Trammo, Ferrostaal in NH_3 MoU: Fertilizer Week, v. 14, no. 12, July 31, p. 1-2.

———2000b, Bulgaria increases AN import duties: Fertilizer Week, v. 14, no. 29, November 27, p. 3.

———2000c, CSBP starts NH_3 commissioning: Fertilizer Week, v. 13, no. 48, April 17, p. 3.

———2000d, Delhi backs off-take deal for Oman-India: Fertilizer Week, v. 14, no. 7, June 26, p. 1.

———2000e, Delhi details urea project moratorium: Fertilizer Week, v. 13, no. 39, February 14, p. 1.

———2000f, DneproAzot NH_3 pipeline plans turned down: Fertilizer Week, v. 13, no. 48, April 17, p. 2.

———2000g, EC urea dumping case official; angry response: Fertilizer Week, v. 14, no. 25, October 30, p. 1, 3.

———2000h, Egyptian Fertilizer Co[.] lines up urea exports: Fertilizer Week, v. 14, no. 22, October 9, p. 3.

———2000i, Engro plans new NPK unit; urea upgrade seen: Fertilizer Week, v. 13, no. 47, April 10, p. 2.

———2000j, EU launches dumping review on Russian AN: Fertilizer Week, v. 14, no. 17, September 4, p. 1-2.

———2000k, EU slaps import duties on Polish, Ukranian AN: Fertilizer Week, v. 14, no. 12, July 31, p. 1.

———2000l, Fertnitro mechanical completion imminent: Fertilizer Week, v. 14, no. 9, July 10, p. 1, 3.

———2000m, Kemira to close Rozenberg N plant: Fertilizer Week, v. 14, no. 1, May 15, p. 1-2.

———2000n, KPI starts construction of ammonia plant: Fertilizer Week, v. 13, no. 41, February 28, p. 3.

———2000o, Management buy-out takes 51% of Neochim: Fertilizer Week, v. 14, no. 6, June 19, p. 2.

———2000p, Mexico in 11th hour urea output deal: Fertilizer Week, v. 13, no. 40, February 21, p. 1.

———2000q, PCS announces NH_3 restart in Trinidad: Fertilizer Week, v. 14, no. 5, June 12, p. 1, 4.

———2000r, PCS Yumbes starts KNO_3 output in Chile: Fertilizer Week, v. 14, no. 14, August 14, p. 2.

———2000s, Petrobras N unit ready; merchant NH_3 to rise: Fertilizer Week, v. 14, no. 31, December 11, p. 2.

———2000t, Petronas begins ammonia commissioning at Kerteh: Fertilizer Week, v. 14, no. 22, October 9, p. 1-2.

———2000u, Plenty River strikes 15-year offtake contracts: Fertilizer Week, v. 14, no. 32, December 18, p. 1-2.

———2000v, Profertil to install NH3 flare stacks: Fertilizer Week, v. 14, no. 30, December 4, p. 1-2.

———2000w, Saudi ibn al-Baytar set for ammonia debottleneck: Fertilizer Week, v. 14, no. 15, August 21, p. 1-2.

———2000x, Sohar NH_3/urea project seen complete by 2004: Fertilizer Week, v. 14, no. 13, August 7, p. 3.

———2000y, Qafco IV approved; output seen mid[-]2004: Fertilizer Week, v. 14, no. 23, October 16, p. 3.

———2000z, QFAL, Uhde, Devco sign MoU on new N complex: Fertilizer Week, v. 13, no. 50, May 8, p. 3.

———2000aa, SQM eyes late-August to start Chile KNO_3 unit: Fertilizer Week, v. 14, no. 8, July 3, p. 1.

———2000bb, Turkish regulator blocks Toros bid for Igsas: Fertilizer Week, v. 14, no. 29, November 27, p. 3.

———2000cc, Ukraine reorganises NH_3 pipeline control: Fertilizer Week, v. 14, no. 25, October 30, p. 3.

Green Markets, 2000a, Agrium-Unocal deal completed; J.R. Simplot buys divested terminal: Green Markets, v. 24, no. 41, October 9, p. 1, 11-12.

———2000b, China trade bill passes Senate 83-15; "new gateways" to fertilizer trade expected: Green Markets, v. 24, no. 39, September 25, p. 1, 12.

———2000c, Explosion idles Farmland's Lawrence plant: Green Markets, v. 24, no. 30, July 24, p. 1.

———2000d, Farmland to sell Coffeyville refinery; keep fert assets: Green Markets, v. 24, no. 50, December 11, p. 10.

———2000e, ISU Extension maps soil temperatures for timely fall fertilizer application: Green Markets, v. 24, no. 39, September 25, p. 9.

———2000f, LaRoche-Orica-Eldorado deal closes; Dyno Orica forge jv on Geneva AN plant: Green Markets, v. 24, no. 45, November 6, p. 1, 12.

———2000g, MissChem to buy IMC-Agrico urea plant: Green Markets, v. 24, no. 14, April 3, p. 8.

———2000h, National Research Council report proposes a reduction in N and P levels: Green Markets, v. 24, no. 15, April 10, p. 1, 12.

———2000i, Nitrogen producers close plants as gas soars: Green Markets, v. 24, no. 51, December 18, p. 1, 11-12.

———2000j, Perdue Agri-Recycle to make chicken-litter fertilizer: Green Markets, v. 24, no. 32, August 7, p. 11.

———2000k, Wil-Gro Fertilizer to liquidate: Green Markets, v. 24, no. 6, February 7, p. 1, 11.

———2001, LaRoche reorganization on track: Green Markets, v. 25, no. 15, April 9, p. 11.

Industrial Minerals, 2000, Norsk/AECI fertiliser j-v: Industrial Minerals, no. 389, February, p. 65.

International Fertilizer Industry Association, 2001a, Ammonia statistics 2000: International Fertilizer Industry Association, A/01/61, May, 12 p.

———2001b, Urea statistics 2000: International Fertilizer Industry Association, A/01/60, May, 22 p.

Nitrogen & Methanol, 2000a, Bangladesh—New urea capacity moving ahead: Nitrogen & Methanol, no. 247, September-October, p. 8.

———2000b, Non-fertilizer uses of ammonia: Nitrogen & Methanol, no. 244, March-April, p. 15-18.

———2000c, Pakistan—Pak-Saudi sale put back: Nitrogen & Methanol, no. 248, November-December, p. 7.

———2000d, United Arab Emirates—SPIC plant "to start up in 2001":

Digitized by Google

Nitrogen & Methanol, no. 247, September-October, p. 8.
U.S. Department of Commerce, International Trade Administration, 2001, Notice of preliminary determination of sales at less than fair value and postponement of final determination—Solid agricultural grade ammonium nitrate from Ukraine: Federal Register, v. 66, no. 43, March 5, p. 13286-13292.
U.S. Environmental Protection Agency, 2000, Revisions to the water quality planning and management regulation and revisions to the national pollutant discharge elimination system program in support of revisions to the water quality planning and management regulation: Federal Register, v. 65, no. 135, July 13, p. 43586-43670.
U.S. International Trade Commission, 2000, Certain ammonium nitrate from Ukraine—Investigation no. 731-TA-894 (preliminary): U.S. International Trade Commission, USITC publication no. 3374, December, 19 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

A National Look at Nitrate Contamination of Ground Water, URL http://water.usgs.gov/nawqa/wcp/index.html.
Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Fertilizers—Sustaining Global Food Supplies. Fact Sheet 155-99, 1999.
Nitrogen. Ch. in Mineral Commodity Summaries, annual.
Nitrogen in the Mississippi Basin—Estimating Sources and Predicting Flux to the Gulf of Mexico. Fact Sheet 135-00, 2000.
Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States. Water-Resources Investigations Report 94-4001, 1994.
Nutrients in the Nation's Waters—Too Much of a Good Thing?. Circular 1136, 1996.

Other

Agricultural Outlook. U.S. Department of Agriculture.
Chemical Market Reporter, weekly.
International Fertilizer Development Center, Muscle Shoals, AL.
International Fertilizer Industry Association, Paris, France.
Nitrogen. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Nitrogen & Methanol. CRU Publishing Ltd., bimonthly.
The Fertilizer Institute, Washington, DC.

TABLE 1
SALIENT AMMONIA STATISTICS 1/ 2/

(Thousand metric tons of contained nitrogen, unless otherwise specified)

	1996	1997	1998	1999	2000 p/
United States:					
Production	13,400	13,300	13,800	12,900 r/	12,300
Exports	435	395	614	562	662
Imports for consumption	3,390	3,530	3,460	3,890	3,880
Consumption, apparent 3/	16,400	15,800	17,100	16,300 r/	15,400
Stocks, December 31; producers'	881	1,530	1,050	996 4/	1,120 4/
Average annual price per ton product, f.o.b. Gulf Coast 5/	$190	$173	$121	$109	$169
Net import reliance as a percentage of percent of apparent consumption 6/	19	16	19	21 r/	20
Natural gas price, wellhead 7/	$2.17	$2.32	$1.94	$2.17 r/	$3.60 e/
World:					
Production	105,000 r/	103,000 r/	105,000	107,000 r/	109,000 e/
Trade 8/	10,900	11,300	11,300	12,000	12,600

e/ Estimated. p/ Preliminary. r/ Revised.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Synthetic anhydrous ammonia, calendar year data, the U.S. Census Bureau; excludes coke oven byproduct.
3/ Calculated from production, plus imports minus exports, and industry stock changes.
4/ Source: The Fertilizer Institute.
5/ Source: Green Markets.
6/ Net import reliance is defined as imports minus exports, adjusted for industry stock changes.
7/ Monthly Energy Review, U.S. Department of Energy. Average annual cost at wellhead in dollars per thousand cubic feet.
8/ Source: International Fertilizer Industry Association Statistics, World Anhydrous Ammonia Trade.

TABLE 2
FIXED NITROGEN PRODUCTION IN THE UNITED STATES 1/

(Thousand metric tons of contained nitrogen)

	1999 r/	2000 p/
Anhydrous ammonia, synthetic:		
Fertilizer	11,400	10,900
Nonfertilizer	1,550	1,490
Total	12,900	12,300

p/ Preliminary. r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Sources: U.S. Census Bureau, Current Industrial Reports MA325B and MQ325B.

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TABLE 3
MAJOR DOWNSTREAM NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES 1/ 2/

(Thousand metric tons)

Compound	1999 r/	2000 p/
Urea:		
Gross weight	8,080	6,950
Nitrogen content	3,710	3,190
Ammonium phosphates: e/ 3/		
Gross weight	16,700	15,800
Nitrogen content	2,820	2,510
Ammonium nitrate:		
Gross weight	7,230	7,480
Nitrogen content	2,450	2,540
Nitric acid:		
Gross weight	8,120	7,980
Nitrogen content	1,790	1,760
Ammonium sulfate: 4/		
Gross weight	2,610	2,600
Nitrogen content	533	552

e/ Estimated. p/ Preliminary. r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Ranked in relative order of importance by nitrogen content.
3/ Diammonium phosphate (DAP), monoammonium phosphate (MAP), and other ammonium phosphates.
4/ Excludes coke plant ammonium sulfate.

Source: U.S. Census Bureau, Current Industrial Reports MQ325B.

TABLE 4
DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 2000 1/

(Thousand metric tons per year of ammonia)

Company	Location	Capacity 2/
Agrium Inc.	Borger, TX	490
Do.	Finley, WA 3/	180
Do.	Kenai, AK 3/	1,210
Air Products and Chemicals Inc.	Pace Junction, FL	71
Avondale Ammonia Co.	Fortier, LA	399
Borden Chemicals Inc.	Geismar, LA 4/	364
CF Industries Inc.	Donaldsonville, LA	1,730
Coastal Chem Inc. 5/	Cheyenne, WY	174
Coastal Refining and Marketing Inc. 5/	Freeport, TX	204
Coastal St. Helens Chemical 5/	St. Helens, OR	93
Dakota Gasification Co.	Beulah, ND	363
E.I. du Pont de Nemours & Co. Inc.	Beaumont, TX	451
El Dorado Chemical Co. 6/	Cherokee, AL	159
Farmland Industries Inc.	Beatrice, NE	272
Do.	Coffeyville, KS 7/	349
Do.	Dodge City, KS	281
Do.	Enid, OK	907
Do.	Fort Dodge, IA	339
Do.	Lawrence, KS	409
Do.	Pollock, LA	459
Green Valley Chemical Corp.	Creston, IA	32
Honeywell International Inc. 8/	Hopewell, VA	409
IMC-Agrico Co.	Faustina (Donaldsonville), LA	508
J.R. Simplot Co.	Pocatello, ID	93
Koch Nitrogen Co.	Sterlington, LA	1,110
MissChem Nitrogen LLC 9/	Yazoo City, MS	621
Nitromite Fertilizer	Dumas, TX	128
PCS Nitrogen Inc.	Augusta, GA	653
Do.	Geismar, LA	483
Do.	Lima, OH	542
Do.	Woodstock, TN	371
Royster-Clark Inc.	East Dubuque, IL	292
Shoreline Chemical	Gordon, GA	31

See footnotes at end of table.

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TABLE 4--Continued
DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 2000 1/

(Thousand metric tons per year of ammonia)

Company	Location	Capacity 2/
Terra Industries Inc.	Beaumont, TX 10/	231
Do.	Blytheville, AR	381
Do.	Port Neal, IA	336
Do.	Verdigris, OK	953
Do.	Woodward, OK	399
Triad Nitrogen LLC 9/	Donaldsonville (Ampro), LA	509
Do.	Donaldsonville (Triad), LA	417
Wil-Grow Fertilizer Co.	Pryor, OK 11/	86
Do.	do. 11/	247
Total		17,700

1/ Data are rounded to no more than three significant digits; may not add to total shown.
2/ Engineering design capacity adjusted for 340 days per year of effective production capability.
3/ Purchased from Unocal Corp.
4/ Closed in July 2000.
5/ Wholly owned subsidiary of Coastal Corp.
6/ Purchased from Orica LLC, which had purchased plant from LaRoche Industries Inc. in 2000. El Dorado Chemical Co. is a wholly owned subsidiary of LSB Industries Inc.
7/ Opened in September 2000.
8/ AlliedSignal Inc. merged with Honeywell Inc. and company was renamed Honeywell International Inc. in 2000.
9/ Wholly owned subsidiary of Mississippi Chemical Corp.
10/ The Beaumont, TX, facility began producing ammonia in January 2000.
11/ Closed in February 2000.

Sources: International Fertilizer Development Center (IFDC) and company web sites.

TABLE 5
U.S. NITROGEN FERTILIZER CONSUMPTION, BY PRODUCT TYPE 1/ 2/

(Thousand metric tons nitrogen)

Fertilizer material 3/	1999	2000 p/
Single nutrient:		
Anhydrous ammonia	3,470 r/	3,310
Nitrogen solutions 4/	2,830 r/	2,720
Urea	1,930 r/	1,960
Ammonium nitrate	578 r/	523
Ammonium sulfate	206 r/	213
Aqua ammonia	66 r/	64
Other 5/	287	285
Total	9,370 r/	9,070
Multiple nutrient 6/	2,090 r/	2,110
Grand total	11,500 r/	11,200

p/ Preliminary. r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Fertilizer years ending June 30.
3/ Ranked in relative order of importance by product type.
4/ Principally urea-ammonium nitrate (UAN) solutions, 29.9% nitrogen (N).
5/ Includes other single-nutrient nitrogen materials, all natural organics, and statistical discrepancies.
6/ Various combinations of N, phosphate (P), and potassium (K): N-P-K, N-P, and N-K.

Source: Commercial Fertilizers 2000. Prepared as a cooperative effort by The Fertilizer Institute and the Association of American Plant Food Control Officials.

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TABLE 6
U.S. PRODUCER STOCKS OF FIXED NITROGEN COMPOUNDS AT YEAREND 1/ 2/

(Thousand metric tons nitrogen)

Material 3/	1999	2000 p/
Ammonia 4/	996	1,120
Nitrogen solutions 5/	W	W
Urea	125	54
Ammonium phosphates 6/	66 r/	83
Ammonium nitrate	W	35
Ammonium sulfate	48	25
Total	1,240	1,310

p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in total.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Calendar year ending December 31.
3/ Ranked in relative order of importance.
4/ Source: The Fertilizer Institute.
5/ Urea-ammonium nitrate and ammoniacal solutions.
6/ Diammonium and monoammonium phosphates.

Source: U.S. Census Bureau, Current Industrial Reports MQ325B, except where noted.

TABLE 7
PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS AT YEAREND

(Dollars per short ton)

Compound	1999	2000
Ammonium nitrate; f.o.b. Corn Belt 1/	110-115	140-150
Ammonium sulfate; f.o.b. Corn Belt 1/	109-112	130-135
Anhydrous ammonia:		
F.o.b. Corn Belt	157-165	280-300
F.o.b. Gulf Coast 2/	109	230
Diammonium phosphate; f.o.b. central Florida	138-140	137-142
Urea:		
F.o.b. Corn Belt, prilled and granular	115-125	175-180
F.o.b. Gulf Coast, granular 2/	107-110	158-161
F.o.b. Gulf Coast, prilled 2/	102	150-155

1/ Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio.
2/ Barge, New Orleans.

Source: Green Markets.

TABLE 8
U.S. EXPORTS OF ANHYDROUS AMMONIA, BY COUNTRY 1/

(Thousand metric tons ammonia)

Country	1999	2000
Brazil	--	17
Canada	27	18
Japan	3	18
Korea, Republic of	547	645
Mexico	21	67
South Africa	--	18
Taiwan	80	2
Other	6 r/	20
Total	684	805

r/ Revised. -- Zero.
1/ Value data supressed by U.S. Census Bureau.

Source: U.S. Census Bureau.

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TABLE 9
U.S. IMPORTS OF ANHYDROUS AMMONIA, BY COUNTRY 1/

(Thousand metric tons ammonia and thousand dollars)

Country	1999		2000	
	Gross weight	Value 2/	Gross weight	Value 2/
Belgium	3	686	--	--
Canada	1,110	190,000	1,050	201,000
Colombia	25	2,850	46	6,340
France	3	326	--	--
Japan	(3/)	74	2	175
Indonesia	--	--	97	14,900
Lithuania	--	--	21	1,790
Mexico	19	2,100	148	21,900
Netherlands	--	--	11	1,820
Peru	(3/)	66	--	--
Russia 4/	1,010	12,300	908	48,500
Switzerland	80	8,200	--	--
Trinidad and Tobago	2,480	276,000	2,430	384,000
Ukraine	NA	55,000	NA	85,600
Venezuela	(3/)	29	9	1,430
Total	4,730	548,000	4,720	768,000

NA Not available. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value.
3/ Less than 1/2 unit.
4/ Quantity data from the Journal of Commerce Port Import/Export Reporting Service; may include imports from Ukraine.

Sources: U.S. Census Bureau, Journal of Commerce Port Import/Export Reporting Service.

TABLE 10
U.S. EXPORTS OF MAJOR NITROGEN COMPOUNDS 1/

(Thousand metric tons)

Compound	1999		2000		Principal destinations, 2000
	Gross weight	Nitrogen content	Gross weight	Nitrogen content	
Ammonium nitrate 2/	28	9	22	7	Mexico, 62%; Canada, 18%.
Ammonium sulfate 2/	1,070	288	983	265	Brazil, 61%.
Anhydrous ammonia	684	562	805	662	Republic of Korea, 80%.
Diammonium phosphate	10,500	1,890	7,620	1,370	China, 58%.
Monoammonium phosphate	1,790	197	2,300	253	Canada, 38%; Australia, 21%; Brazil, 12%.
Urea	890	409	663	304	Mexico, 24%; Thailand, 21%; Republic of Korea, 12%.
Mixed chemical fertilizers 3/	268	32	273	33	Colombia, 30%; Mexico, 27%.
Other nitrogenous fertilizers 4/	204	60	207	61	Mexico, 37%; Canada, 11%.
Total	15,400	3,450	12,900	2,960	

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes industrial chemical products.
3/ Harmonized Tariff Schedule codes 3105.10.0000, 3105.20.0000, and 3105.51.0000.
4/ Harmonized Tariff Schedule codes 3101.00.0000, 3102.29.0000, 3102.60.0000, and 3102.90.0000.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS OF MAJOR NITROGEN COMPOUNDS 1/

(Thousand metric tons and thousand dollars)

Compound	1999			2000			Principal sources, 2000
	Gross weight	Nitrogen content	Value 2/	Gross weight	Nitrogen content	Value 2/	
Ammonium nitrate 3/	935	317	111,000	818	277	93,700	Canada, 57%; Ukraine, 34%.
Ammonium nitrate-limestone mixtures	10	3	1,970	1	(5/)	173	Canada, 81%.
Ammonium sulfate 3/	342	73	34,500	347	74	32,400	Canada, 79%; Belgium, 10%.
Anhydrous ammonia 4/	4,730	3,890	548,000	4,720	3,880	768,000	Trinidad and Tobago, 51%; Canada, 22%; Russia and Ukraine, 19%.

See footnotes at end of table.

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TABLE 11--Continued
U.S. IMPORTS OF MAJOR NITROGEN COMPOUNDS 1/

(Thousand metric tons and thousand dollars)

Compound	1999 Gross weight	1999 Nitrogen content	1999 Value 2/	2000 Gross weight	2000 Nitrogen content	2000 Value 2/	Principal sources, 2000
Calcium nitrate	(5/)	(5/)	12,500	(5/)	(5/)	9,890	Norway, 88%.
Diammonium phosphate	36	6	8,360	123	22	21,900	Russia, 90%.
Monoammonium phosphate	47	5	18,800	188	21	40,700	Russia, 88%.
Nitrogen solutions	614	184	54,600	1,310	390	129,000	Russia, 34%; Canada, 22%; Ukraine, 20%.
Potassium nitrate	21	3	6,980	41	6	13,700	Chile, 85%.
Potassium nitrate-sodium nitrate mixtures	16	2	2,970	9	1	1,660	Chile, 98%.
Sodium nitrate	105	17	22,900	98	16	20,100	Chile, 96%.
Urea	3,260	1,500	486,000	3,900	1,790	621,000	Canada, 46%; Saudi Arabia, 12%.
Mixed chemical fertilizers 6/	262	31	60,900	257	31	61,500	Canada, 18%; Norway, 17%; Ukraine, 17%; Morocco, 16%.
Other nitrogenous fertilizers 7/	202	60	40,200	207	61	39,500	Norway, 71%.
Total	10,600	6,090	1,410,000	12,000	6,570	1,850,000	

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value
3/ Includes industrial chemical products.
4/ Includes industrial ammonia.
5/ Less than 1/2 unit.
6/ Harmonized Tariff Schedule codes 3105.10.0000, 3105.20.0000, 3105.51.0000, and 3105.90.0050.
7/ Harmonized Tariff Schedule codes 3101.00.0000, 3102.29.0000, 3102.60.0000, and 3102.90.0000.

Source: U.S. Census Bureau.

TABLE 12
AMMONIA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of contained nitrogen)

Country	1996	1997	1998	1999	2000
Afghanistan e/	5	5	5	5	5
Albania e/	15	10	10	10	10
Algeria	150	380 e/	350	455	458
Argentina	80	107	86	88	199
Australia	446	432 e/	435 r/	431	576
Austria e/	450	450	450	450	500
Bahrain	323	356	336	370	350
Bangladesh 3/	1,233	1,080	1,129 r/	1,240	1,255
Belarus	678	590 e/	685	765 r/	730
Belgium	750	760	756	840	863
Bosnia and Herzegovina e/	1	1	1	1	1
Brazil	977	1,019	949	1,084	925 e/
Bulgaria	1,194	808	448	315 e/	533
Burma	57	62	52	66 r/	78
Canada	3,840	4,081	3,900	4,135	4,130
China e/	25,200 r/	24,800 r/	26,100 r/	27,800 r/	28,000
Colombia	102	81	100	75	93 e/
Croatia	307	331	248	318	325
Cuba e/	135	135	135	135	135
Czech Republic	304	251	258	223	246
Denmark e/	2	2	2	2	2
Egypt	1,126	1,061	1,141	1,407	1,511
Estonia	137 r/	153 r/	175 r/	146 r/	128
Finland e/	5 r/ 4/	6	6	6	6
France e/	1,570	1,757 4/	1,570	1,570	1,700
Germany	2,485	2,470	2,512	2,406	2,473
Georgia	77	84	64	104 e/	1 e/
Greece	90	83 e/	178	160	121
Hungary	347	339	288	261	352
Iceland	7	7	6	7 e/	7 e/
India 5/	8,549	9,328	10,240 r/	10,376	10,148

See footnotes at end of table.

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TABLE 12--Continued
AMMONIA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of contained nitrogen)

Country	1996	1997	1998	1999	2000
Indonesia	3,647	3,769	3,600	3,450 r/	4,000 e/
Iran	882	880	1,034	865 e/	965
Iraq e/	220	220	220	220	220
Ireland	377	465	458	405	410
Israel 3/	65	57	1	-- e/	-- e/
Italy	397	446	409	367	408
Japan	1,490 r/	1,509 r/	1,389 r/	1,385 r/	1,405
Kazakhstan	75	75 e/	--	-- e/	-- e/
Korea, North e/	600	600	600	500	450
Korea, Republic of	611 r/	526 r/	496 r/	489 r/	400 e/
Kuwait	412	432 e/	452	397	410
Libya	546	537	545	552	552 e/
Lithuania	461	467 r/	407 r/	401 r/	420
Malaysia	329	243	351	432 e/	605
Mexico	2,054	1,448	1,449 r/	1,003	701
Netherlands	2,652	2,478 r/	2,350 e/	2,430 e/	2,543
New Zealand	68	80	94	110	105
Nigeria e/	164	134	168	148	--
Norway	295	279	245	122 r/	334
Pakistan	1,606	1,549	1,797	1,999	1,884
Peru	18	15	15	-- e/	-- e/
Poland	1,713	1,824	1,683	1,474	1,862
Portugal	198	196	204	223	246 e/
Qatar	635 r/	943	1,127	1,130	1,097
Romania	1,513	781	378	686	1,016
Russia	7,900	7,150	6,500	7,633	8,735
Saudi Arabia	1,386	1,405	1,418	1,402	1,743
Serbia and Montenegro	235 r/	235 r/	172 r/	57 r/	100 e/
Slovakia	197	229	234 r/	246 r/	271
South Africa	770	752	723	785	560
Spain	466	497	460	437	442 e/
Switzerland e/	32	32	31	32	33
Syria	80	84	129	112	91
Taiwan	252	289	231	146	11 e/
Tajikistan e/	10	10	10	10	1
Trinidad and Tobago	1,801	1,772	2,271	2,720	2,686
Turkey	519	558	560	82	53
Turkmenistan	70	61	75 e/	75 e/	75 e/
Ukraine	3,300	3,400 e/	3,300	3,711	3,577
United Arab Emirates	331	373	331	380	348
United Kingdom	850	642	871	902	814 e/
United States 6/	13,400	13,300	13,800	12,900 r/	12,300
Uzbekistan	950	950	875	790 e/	810 e/
Venezuela	605	612	522	522 r/ e/	377 e/
Vietnam	54	54 e/	33	33 e/	42
Zambia	2	1 e/	--	-- e/	-- e/
Zimbabwe e/	61	64	57	61	58
Total	105,000 r/	103,000 r/	105,000	107,000 r/	109,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 2001.

3/ May include nitrogen content of urea.

4/ Reported figure.

5/ Data are for years beginning April 1 of that stated.

6/ Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

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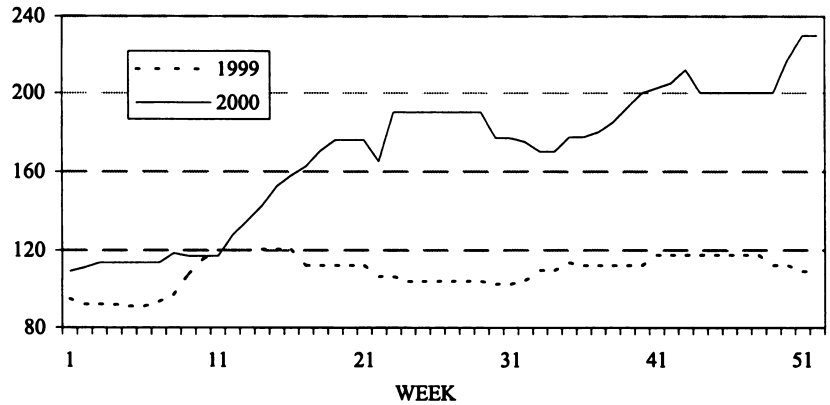
FIGURE 1
AVERAGE GULF COAST AMMONIA PRICES

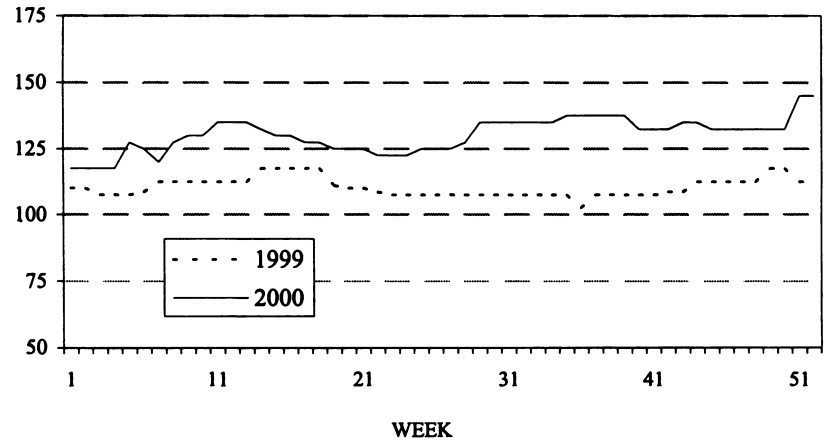
(Dollars per short ton)



Source: Green Markets.

FIGURE 2
AVERAGE GULF COAST GRANULAR UREA PRICES

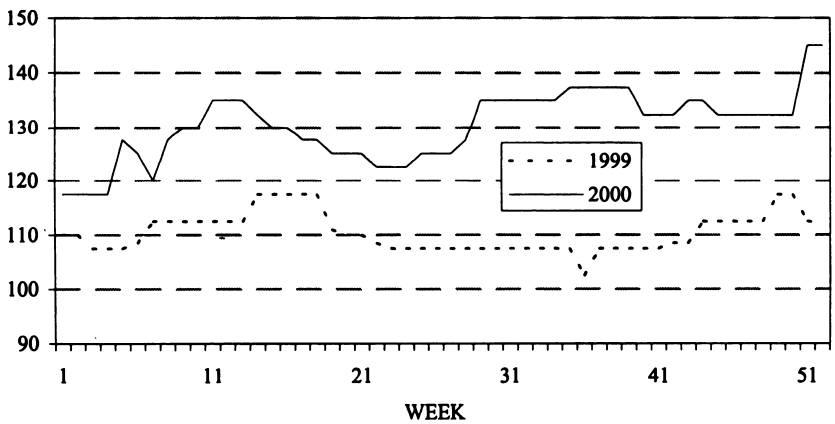
(Dollars per short ton)



Source: Green Markets.

FIGURE 3
AVERAGE AMMONIUM NITRATE PRICES

(Dollars per short ton)



Source: Green Markets.

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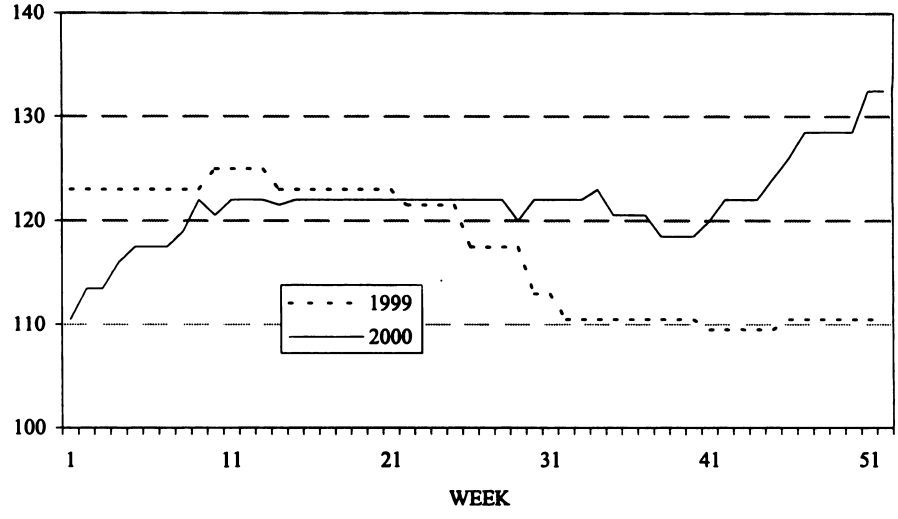
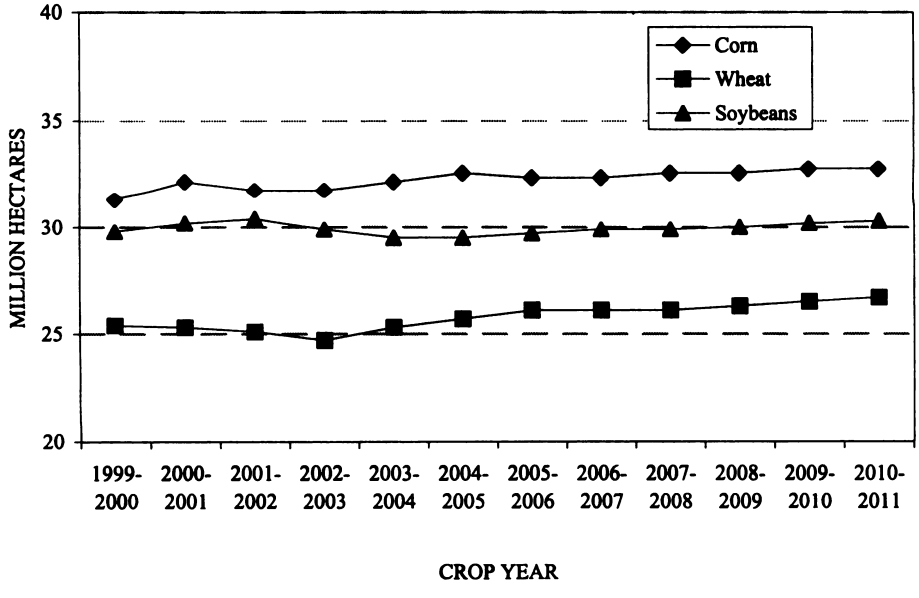
FIGURE 4
AVERAGE AMMONIUM SULFATE PRICES

(Dollars per short ton)



Source: Green Markets.

FIGURE 5
PROJECTED PLANTED ACREAGE



Source: U.S. Department of Agriculture.

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PEAT

By Stephen M. Jasinski

Domestic survey data and tables were prepared by Jeff Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Peat is a renewable, natural, organic material of botanical origin and of commercial significance. Peatlands are situated predominately in shallow wetland areas of the Northern Hemisphere, where large deposits developed from the gradual decomposition of plant matter under anaerobic conditions.

Peat has widespread use as a plant-growth medium in a variety of horticultural and agricultural applications, where its fibrous structure and porosity promote a unique combination of water-retention and drainage characteristics. Commercial applications include potting soils, lawn and garden soil amendments, and turf maintenance on golf courses. In industry, peat is used primarily as a filtration medium to remove toxic materials from process waste streams, pathogens from sewage effluents, and deleterious materials suspended in municipal storm-drain water. In its dehydrated form, peat is a highly effective absorbent for fuel and oil spills on land and water.

The United States remained a significant producer and consumer of peat for horticultural, agricultural, and industrial purposes. A variety of peat types were extracted and processed from 61 identified operations in 17 of the conterminous United States and by several companies in Alaska. The grades of peat included, in order of importance, reed-sedge, sphagnum moss, hypnum moss, and humus. Florida, Michigan, and Minnesota accounted for 78% of U.S. production. The United States imported one-half of its total domestic requirements, principally from Canada, where deposits of high-quality sphagnum moss are extensive.

U.S. production and sales of peat increased for the fifth consecutive year (table 1). Imports of sphagnum peat from Canada increased by 5%.

Production

Domestic production data for peat were developed from a voluntary survey of operations in the conterminous United States by the U.S. Geological Survey (USGS). Of the 64 operations to which a survey request was sent, 46 responded, representing 75% of total production. Peat production in 2000 was 755,000 metric tons (t), a 3% increase from that of 1999 (table 2).

Geographically, domestic production was dominated by operations in Florida, Michigan, and Minnesota (table 3). Reed-sedge peat accounted for 80.5% of production by weight, followed by hypnum moss, 7.2%; sphagnum moss, 6.4%; and humus, 5.9% (table 4). Peat production in Alaska was estimated to be 30,600 cubic meters in 2000, according to the Alaska Department of Natural Resources (Szumigala and Swainbank, 2001, p. 12), which conducted its own survey of mineral production in the State. Only volume of production was reported.

Consumption

Sales of domestic peat increased by 2% to 847,000 t compared with that of 1999. Packaged products composed 43% of total domestic sales tonnage and commanded premium prices

Peat in the 20th Century

Domestic commercial production of peat was first recorded in 1904, although peat had been used as fuel in New England since the colonial era and was still harvested for local or individual use. By 1908, commercial production of peat had grown to nearly 23,000 metric tons from less than 1,000 tons in 1904. The largest use was as a filler material in chemical fertilizers. Dried, ground peat was added to the fertilizer product to provide nitrogen and improve the consistency and water holding capability. Peat also was used for stable litter and was combined with molasses residue for use as stock feed. Early in the century, considerable interest was given to using peat as a fuel source, especially after a strike by anthracite coal miners in 1902 to 1903. Some small peat powerplants did operate intermittently throughout the century, but abundant U.S. resources of wood, coal, oil, and natural gas made it difficult for peat to be a cost-effective fuel source. Peat was harvested by draining the bog, plowing the peat, and forming it into windrows to air dry. When the peat had dried to about 50% moisture, it was transported to a mechanical dryer, which lowered the moisture content to 10%. It was then screened to remove waste matter and sold. At the end of the century, peat was harvested by the same basic methods; such specialized machinery as the pneumatic harvester, however, greatly improved efficiency. From about 1930 to 2000, peat had been used primarily as a soil conditioner in such applications as golf course improvement, potting soil mixes, general nursery use, and vegetable growing.

In 2000, the United States produced 755,000 tons of peat and imported 786,000 tons, mostly from Canada. Consumption grew steadily in the 1990s as horticultural business benefited from demand generated by new construction of houses, commercial buildings, golf courses, and recreational facilities. The total sales value of domestic peat in 2000 was $22.7 million, and imports were valued at $157 million. World production was estimated to have been about 27 million metric tons, with more than one-half used as fuel.

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for all grades except humus. Apparent consumption decreased by 5% from that of 1999. General soil improvement and potting soil mixes were the two largest usage categories, accounting for 82% of domestic sales. Other significant uses included mixed fertilizers, nursery applications, golf course applications, and seed inoculants. Imports of sphagnum moss from Canada accounted for nearly 50% of U.S. consumption. Canadian peat was sold in bulk for blending in soil mixes and packaged for horticultural use.

Scotts Co. purchased the worldwide distribution rights for horticultural peat and peat products manufactured by Bord na Móna plc of Ireland. Scotts will market the products under the Shamrock® brand, which it had acquired from Bord na Móna in 1998 for distribution in Ireland and the United Kingdom. Currently [2000], the products are marketed to professional growers but will be expanded to the consumer market in the future (Scotts Co., 2000).

Stocks

U.S. yearend stocks of peat increased by 3% to 279,000 t (table 4). Reed-sedge peat accounted for 92% of total stocks, followed by humus, sphagnum moss, and hypnum moss.

Prices

The total reported free on board (f.o.b.) value for domestic peat sold in the United States was $22.7 million according to the annual survey of domestic peat producers conducted by the USGS. The average unit value increased to $26.85 per metric ton compared with $26.48 per ton in 1999. Packaged peat sold for a higher value for all grades except humus. On a unit-value basis, packaged sphagnum moss was valued at $68.42 per ton, f.o.b. plant; hypnum moss, $52.47 per ton; reed-sedge, $24.33; and humus, $17.86 per ton (table 7).

Foreign Trade

Imports of peat increased by 3% to 786,000 t in 2000 (table 8). The total customs import value was $157 million or $199.65 per ton. Imports of sphagnum moss from Canada increased to 783,000 t, which represented 64% of total Canadian production. The United States exported 37,000 t of peat.

World Review

World production decreased to 27.4 million metric tons (Mt) in 2000 compared with 29.5 Mt in 1999. According to information available to the USGS, 22 countries reported peat production (table 9). Production was dominated, in order of importance, by Finland, Ireland, Germany, Belarus, Russia, and Canada. Other significant producing counties included Sweden, Estonia, the United States, and Latvia. Peat is an important source of energy in Ireland, Scandinavia, and the former Soviet Union (FSU). In 2000, at least 14.7 Mt of reported world production was for fuel use. Most of the unspecified uses were believed to have been for horticultural use; however, information was not available to make an accurate estimate.

Estimated production from countries of the FSU accounted for a significant portion of global peat production, although output from the region has decreased since 1990. Political restructuring, the reduced use of peat as a fuel, and unfavorable economic trends were all believed to have been major factors responsible for the drop in production.

In Canada, production of sphagnum moss decreased by 7% to 1.23 Mt (table 9). New Brunswick, Quebec, and Alberta were the major producing provinces, in order of importance (Natural Resources Canada, 2000, Preliminary estimate of the mineral production of Canada, by province—2000, accessed July 27, 2001, at URL http://www.nrcan.gc.ca/mms/efab/mmsd/production/2000.pdf). Exports to the United States increased to 783,000 t.

Outlook

The outlook for horticulture and associated business is bright because global demand for plants, flowers, ornamental trees, natural turf, and outdoor recreational activities continues to grow at a substantial rate. The outlook for the domestic peat industry, therefore, will likely be governed by several variables, including future wetlands environmental regulations, the ability to permit new bogs, growth and competition from recycled yard wastes and other natural organic materials, Canadian competition, and the degree of market penetration by flowers and ornamental plants from abroad.

References Cited

Scotts Co., 2000, Scotts completes global peat distribution purchase: Columbus, OH, Scotts Co. press release, March 29, 2 p.

Szumigala, D.J., and Swainbank, R.C., 2001, Alaska's mineral industry 2000—A summary: Fairbanks, AK, Alaska Department of Natural Resources Information Circular 47, 15 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Peat. Ch. in Mineral Commodities Summaries, annual.

Peat. Ch. in Minerals Yearbook, annual.

Peat. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Lappalainen, Eino, ed., 1996, Global peat resources: Jyväskylä, Finland, International Peat Society, 360 p.

Peat. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Thibault, J.J., 2001, Peat industry review 2000: New Brunswick Department of Natural Resources and Energy, Bathurst, NB, Canada, 4 p.

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TABLE 1
SALIENT PEAT STATISTICS 1/

(Thousand metric tons, unless otherwise specified)

		1996	1997	1998	1999	2000
United States: 2/						
Number of active producers		59	56	60	58	61
Production		549	661	685	731	755
Sales by producers		640	753	791	834	847
Bulk		325	432	399	444	483
Package		314	320	392	390	364
Value of sales	thousands	$18,500	$17,500	$19,200	$22,100	$22,700
Average per metric ton		$28.90	$23.23	$24.26	$26.48	$26.85
Average per metric ton, bulk		$23.90	$21.65	$24.98	$25.83	$23.45
Average per metric ton, packaged or baled		$34.00	$25.34	$23.52	$27.23	$31.36
Exports		19	22	30	40	37
Imports for consumption		667	754	761	752	786
Consumption, apparent 3/		1,240	1,310	1,430	1,580	1,500
Stocks, December 31, producers'		342	421	408	272	279
World production		29,300 r/	30,200 r/	18,700 r/	29,500 r/	27,400 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except average values per metric ton.

2/ Exclusive of Alaska.

3/ Apparent consumption equals U.S. production plus imports minus exports plus adjustments for industry stock changes.

TABLE 2
RELATIVE SIZE OF PEAT OPERATIONS IN THE UNITED STATES

Size	Active operations		Production (thousand metric tons)	
(metric tons per year)	1999	2000	1999	2000
23,000 and over	10	9	563	559
9,000 to 22,999	3	5	46	67
5,000 to 8,999	12	10	77	72
2,000 to 4,999	9	11	32	41
1,000 to 1,999	6	6	9	10
Under 1,000	18	20	4	6
Total	58	61	731	755

TABLE 3
U.S. PEAT PRODUCTION AND SALES BY PRODUCERS IN 2000, BY STATE 1/

Region and State	Active operations	Production, (thousand metric tons)	Sales		
			Quantity (thousand metric tons)	Value 2/ (thousands)	Percent packaged
East:					
Florida	8	379	416	$8,640	9
Pennsylvania	4	7	6	183	35
Other 3/	7	24	30	1,010	38
Total or average	19	410	453	9,830	11
Great Lakes:					
Michigan	10	189	207	5,750	88
Minnesota	12	64	75	5,100	61
Other 4/	13	76	98	1,790	86
Total or average	35	330	380	12,600	82
West 5/	7	15	14	264	4
Grand total or average	61	755	847	22,700	43

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Values for f.o.b. producing plant.

3/ Includes Maine, New Jersey, New York, North Carolina, and West Virginia.

4/ Includes Illinois, Indiana, Ohio, and Wisconsin.

5/ Includes Iowa, Montana, and Washington.

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TABLE 4
U.S. PEAT PRODUCTION AND PRODUCERS' YEAREND STOCKS IN 2000, BY TYPE

Type	Active operations	Production 1/ (metric tons)	Percent of production	Yearend stocks 1/ (metric tons)
Sphagnum moss	9	48,000	6.4	2,760
Hypnum moss	9	54,500	7.2	1,630
Reed-sedge	30	607,000	80.5	256,000
Humus	15	44,800	5.9	19,200
Total	61 2/	755,000	100.0	279,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Some plants produce multiple types of peat; may not add to totals shown.

TABLE 5
U.S. PEAT SALES BY PRODUCERS IN 2000, BY TYPE AND USE 1/

	Sphagnum moss			Hypnum moss			Reed-sedge		
	Quantity			Quantity			Quantity		
Use	Weight (metric tons)	Volume 2/ (cubic meters)	Value (thousands)	Weight (metric tons)	Volume (cubic meters)	Value (thousands)	Weight (metric tons)	Volume (cubic meters)	Value (thousands)
Earthworm culture medium	19	116	$2	--	--	--	466	719	$9
General soil improvement	40,000	214,000	2,870	10,800	17,700	$557	332,000	580,000	6,540
Golf courses	7,790	36,600	586	1,230	2,290	30	13,800	37,500	2,140
Ingredient for potting soils	1,710	7,190	75	48,500	77,200	1,480	244,000	410,000	4,720
Mixed fertilizers	5,920	22,900	344	--	--	--	22,700	38,200	475
Mushroom beds	--	--	--	--	--	--	--	--	--
Nurseries	1,830	9,670	96	5,900	10,700	144	46,500	77,500	996
Packing flowers, plants, shrubs, etc.	13,100	91,700	624	454	765	11	21	38	1
Seed inoculant	64	395	6	4,540	7,650	120	8,710	8,410	114
Vegetable growing	--	--	--	1,230	2,290	30	2,270	3,820	48
Other	115	485	2	--	--	--	1,070	1,530	14
Total	70,500	383,000	4,610	72,600	119,000	2,380	671,000	1,160,000	15,100

	Humus			Total		
	Quantity			Quantity		
	Weight (metric tons)	Volume (cubic meters)	Value (thousands)	Weight (metric tons)	Volume (cubic meters)	Value (thousands)
Earthworm culture medium	1,070	1,640	$18	1,550	2,480	$30
General soil improvement	5,950	8,710	125	389,000	820,000	10,100
Golf courses	272	382	3	23,100	76,800	2,760
Ingredient for potting soils	11,700	11,400	189	306,000	506,000	6,460
Mixed fertilizers	860	1,040	21	29,500	62,100	839
Mushroom beds	181	141	10	181	141	10
Nurseries	1,380	1,850	32	55,600	99,700	1,270
Packing flowers, plants, shrubs, etc.	2,020	3,060	33	15,600	95,600	669
Seed inoculant	--	--	--	13,300	16,500	240
Vegetable growing	1,080	1,570	22	4,580	7,680	100
Other	7,920	9,980	241	9,110	12,000	258
Total	32,500	39,800	694	847,000	1,700,000	22,700

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Volume of nearly all sphagnum moss was measured after compaction and packaging.

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TABLE 6
AVERAGE DENSITY OF DOMESTIC PEAT SOLD IN 2000 1/

(Kilograms per cubic meter)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus
Bulk	235	612	597	733
Package	173	617	558	970
Bulk and package	184	613	579	817

1/ To convert kilograms per cubic meter to pounds per cubic yard multiply by 1.685.

TABLE 7
PRICES FOR PEAT IN 2000 1/

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Average
Domestic:					
Bulk:					
Per metric ton	55.21	29.76	21.02	23.90	23.45
Per cubic meter	12.98	18.21	12.54	17.52	13.42
Packaged or baled:					
Per metric ton	68.42	52.47	24.33	17.86	31.36
Per cubic meter	11.82	32.37	13.57	17.33	13.33
Average:					
Per metric ton	65.33	32.71	22.43	21.37	26.85
Per cubic meter	12.03	20.04	13.00	17.45	13.38
Imported, total, per metric ton 2/	XX	XX	XX	XX	199.65

XX Not applicable.
1/ Prices are f.o.b. plant.
2/ Average customs value.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PEAT MOSS, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Canada	750,000	$149,000	783,000	$156,000
Denmark	575	152	1,710	512
Finland	284	38	153	41
Ireland	543	71	651	109
Latvia	--	--	518	127
Netherlands	125	89	81	26
Sri Lanka	145	30	--	--
Other 3/	116	151	123	131
Total	752,000	149,000	786,000	157,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.
3/ Includes Chile, China (2000), France (2000), Germany, New Zealand, Norway (1999), and Taiwan.

Source: U.S. Census Bureau.

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TABLE 9
PEAT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
Australia e/	15	15	15	15	3
Belarus:					
Horticultural use	533	253	99	100	100
Fuel use	2,847	2,768	2,035	2,000	2,000
Total	3,480 r/	3,021 r/	2,134 r/	2,100 r/	2,100
Burundi	10	10 r/	10 r/	17 r/ 4/	15
Canada, horticultural use	901	1,054	1,132	1,321 r/ 4/	1,229 4/
Denmark, horticultural use e/	204 4/	205	205	200	200
Estonia, horticultural and fuel use	1,100 r/	1,002 r/	365	923	1,000
Finland: e/					
Horticultural use	300 r/	600 r/	150 r/	800 r/	400
Fuel use	7,000 r/	9,500 r/	1,700 r/	8,000 r/	7,000
Total	7,300 r/	10,100 r/	1,850 r/	8,800 r/	7,400
France, horticultural use e/	200	200	200	200	200
Germany: e/					
Horticultural use	2,800	2,800	2,800	2,800	2,800
Fuel use	180	180	180	180	180
Total	2,980	2,980	2,980	2,980	2,980
Hungary, horticultural use e/	45	45	45	45	45
Ireland:					
Horticultural use e/	400 r/	400 r/	400 r/	350 r/	400
Fuel use	6,578	3,851	4,000 r/ e/	5,300	5,100
Total	6,978 r/	4,251	4,400 r/ e/	5,650 r/	5,500
Latvia, horticultural and fuel use	552	555 r/	172	683 4/	650
Lithuania, horticultural and fuel use	250 e/	295	202 r/	380 r/ 4/	350
Moldova e/ 5/	463 4/	475	475	475	475
Norway, horticultual use e/	30	30	30	30	30
Poland, horticultural and fuel use	198	206	213 r/	200	200
Russia 5/	1,500 r/	2,100 r/	1,700	2,000	2,000
Spain e/	60	60	60	50	50
Sweden: e/					
Horticultural use	300	350	200	440 r/	300
Fuel use	700	1,000	120	800	400
Total	1,000	1,350	320	1,240 r/	700
Ukraine e/ 5/	1,000	1,000	1,000	1,000	1,000
United Kingdom e/	550	550	500	500	500
United States, horticultural use	549	661	685	731	755 4/
Grand total	29,300 r/	30,200 r/	18,700 r/	29,500 r/	27,400
Of which:					
Horticultural use	6,260 r/	6,600 r/	5,950 r/	7,020 r/	6,460
Fuel use	17,300 r/	17,300 r/	8,040 r/	16,300 r/	14,700
Unspecified	5,700 r/	6,270 r/	4,710 r/	6,240 r/	6,240

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through June 25, 2001.

3/ In addition to the countries listed, Austria, Iceland, and Italy produced negligible amounts of peat.

4/ Reported figure.

5/ Production appears to be for fuel use.

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PERLITE

By Wallace P. Bolen

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

In 2000, whereas imports of processed perlite increased compared with 1999, the amount of domestic processed perlite sold and used decreased. The amount of perlite expanded, sold, and used by domestic expanders also decreased in 2000. Increased demand for horticultural aggregates, loose fill insulation, and miscellaneous uses was more than offset by decreases in demand for construction products, fillers, laundries, low temperature insulation, and plaster aggregate.

Production

According to the U.S. Geological Survey (USGS), the amount of U.S. processed perlite sold or used decreased by about 5.5% to 672,000 metric tons (t) compared with that of 1999. The value of processed perlite sold or used decreased by 4.4% to $22.7 million compared with that of 1999. The amount of expanded perlite sold or used by domestic producers decreased 1.9% to 715,000 t, and the associated value remained about the same compared with that of 1999 (table 1).

Domestic production data for perlite are derived by the USGS from two voluntary annual surveys—one for domestic mine operations (processed perlite) and one for expanding plants. All the processed perlite included in table 1 was produced by 11 mines operated by 9 companies, and 9 of the 11 operations responded to the USGS survey. The perlite was mined in Arizona, California, Idaho, Nevada, New Mexico, Oregon, and Utah; New Mexico operations accounted for the vast majority of the total tonnage mined. Ore producers, in alphabetical order by State, were Harborlite Corp. in Arizona and New Mexico; American Perlite Co. in California; Idaho Minerals LLC in Idaho; Wilkins Mining and Trucking, Inc. and Eagle-Picher Minerals, Inc., in Nevada; Cornerstone Industrial Minerals Corp. in Oregon; Dicaperl Corp. and USG Corp. in New Mexico; and Basin Perlite Co. in Utah. Of the 63 expanding operations canvassed, 62 were active. Of those, 49 operations (78%) responded, reporting about 90% of the total expanded perlite sold or used (table 1). The top seven producers of expanded perlite, each with production of more than 30,000 metric tons per year, accounted for nearly 85% of expanded perlite sold or used in the United States in 2000. The remaining 15% was sold or used by 26 companies.

Consumption

Domestic apparent consumption is defined as U.S. processed perlite sold and used plus imports minus exports. In 2000, domestic apparent consumption of processed perlite was 809,000 t, a slight increase compared with that of 1999. Consumption of expanded perlite for construction-related uses, which was the major market for expanded material, decreased by 5.9% to 494,000 t. Construction uses of expanded perlite, which consisted of concrete aggregate, formed products,

Perlite in the 20th Century

Expanded perlite was not available in 1900, because the effect of heat treatment to expand perlite was not discovered until 1928, and controlled experiments using perlite from near Superior, AZ, were not undertaken until 1940. Although not extensively used until 1945, expanded perlite was being used as a lightweight aggregate, as loose fill for insulation, and as chicken litter, while the finest grained perlite was being used in cleansers. The building boom after World War II helped perlite gain market share in competition with expanded slag, clay, vermiculite, and other lightweight materials. At least nine companies were actively experimenting on perlite expansion, and several hundred metric tons had been produced commercially in Arizona, California, and Nevada. After several years of pilot-plant development, the perlite industry started commercial production in 1946, when the output reached 3,820 tons. Five companies reported production, mostly from the Superior area of Arizona and one from near Beatty, NV. All of the material sold in 1946 was used by the construction industry as thermal insulation and lightweight aggregate. The average price of processed perlite was about $41 per ton in 1946. By 1948, it had dropped to about $21.50 per ton. In 1948, the first statistics for expanded perlite were available: 36,700 tons valued at $1.98 million, or about $54 per ton, was produced.

By 2000, production of processed perlite in the United States was 672,000 tons and expanded perlite consumption was 715,000 tons. Imports of perlite were about 180,000 tons. Domestic production was mainly from mines in New Mexico with much smaller amounts coming from mines in Arizona, California, Idaho, Nevada, Oregon, and Utah. Most of the expanded perlite was produced east of the Mississippi River. Construction related uses accounted for most expanded perlite consumption, but instead of being used as loose insulation or aggregate, most of the expanded perlite was used in formed products such as ceiling tiles.

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masonry- and cavity-fill insulation, and plaster aggregate accounted for about 69% of total domestic sales in 2000. Expanded perlite consumption increased for horticultural aggregate, masonry- and cavity- fill insulation, and miscellaneous uses. Consumption decreased for all other uses (table 3). Perlite was expanded, usually for local consumption, in 31 States. The leading States in production of expanded perlite sold or used were, in descending order, Mississippi, Georgia, Illinois, Pennsylvania, Alabama, Minnesota, and Virginia (table 2).

Prices

Processed perlite sold at an average value of $34.39 per metric ton, which was up 2.8% compared with that of 1999. Perlite consumed by expanding plants operated by the mining companies was valued at $30.69 per ton, which was a decrease of 7.4% compared with that of 1999. The average price for all perlite sold or used by mining companies was $33.78 per ton, which was up 1.1% compared with that of 1999. The average price of expanded perlite was $207 per ton, up from $203 in 1999; the range in reported prices was, however, wide—from less than $100 to more than $1,000 per ton.

The average prices by use per ton of expanded perlite, in descending order, were low-temperature insulation, $410; fillers, $402; masonry- and cavity-fill insulation, $401; filter aid, $322; concrete aggregate and horticultural aggregate (tied), $318; plaster aggregate, $300; laundries, $277; and formed products, $144 (table 3).

Foreign Trade

Exports of processed and expanded perlite, primarily to Canada, were estimated to be 43,000 t, which was a 9% decrease from that of 1999. Imports of processed perlite, almost exclusively from Greece, increased by about 25% to about 180,000 t. Import and export data were derived from U.S. Census Bureau data, the Journal of Commerce's Port Import and Export Reporting Service, and importers and exporters.

World Review

The United States was estimated to be the largest producer and consumer of crude and expanded perlite. Other leading producers of processed crude perlite were, in descending order, Greece, Japan, Hungary, and Turkey (table 4). In 2000, 13 countries produced 1.91 million metric tons of perlite. Owing to a lack of reliable figures, however, this total does not include several producing countries, such as China, which was probably the largest or second largest producer in the world.

Outlook

Total consumption of expanded perlite and processed perlite in the United States is expected to increase slightly in 2001. Growth in imports of processed perlite is expected to slow the growth of domestic processed perlite sales. The growth in Canadian horticultural perlite demand may, however, result in increased exports of domestic processed perlite. The new mines in the Western United States and continued growth in imports are expected to restrain price increases for many grades of processed perlite.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Lightweight Aggregates. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Perlite. Ch. in Mineral Commodity Summaries, annual.

Other

Bates, R.L., 1969, Perlite, *in* Igneous rocks, chap. 3 *of* The industrial rocks, pt. II *of* Geology of the industrial rocks and minerals: New York, Dover Publications Inc., p. 50-58.
Harben, P.W., and Bates, R.L., 1990, Perlite, *in* Industrial minerals—Geology and world deposits: London, Metal Bulletin Plc, p. 184-189.
Industrial Minerals Magazine (London).
Perlite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
PERLITE MINED, PROCESSED, EXPANDED, AND SOLD OR USED BY PRODUCERS IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

		Processed perlite					Expanded perlite		
		Sold to expanders		Used at own plant to make expanded material		Total quantity	Quantity	Sold or used	
Year	Perlite mined 2/	Quantity	Value	Quantity	Value	sold or used	produced	Quantity	Value
1996	811	565	17,500	120	3,770	684	671	670	137,000
1997	656	605	19,900	101	3,400	706	700	695	143,000
1998	832	583	18,800	102	3,060	685	738	736	148,000
1999	821	619	20,700	92	3,050	711	731	729	148,000
2000	873	570	19,600	101	3,100	672	715	715	148,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Crude ore mined and stockpiled for processing.

TABLE 2
EXPANDED PERLITE PRODUCED AND SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

	1999				2000			
		Sold or used				Sold or used		
State	Quantity (metric tons)	Quantity (metric tons)	Value (thousands)	Average value per ton 2/	Quantity (metric tons)	Quantity (metric tons)	Value (thousands)	Average value per ton 2/
California	29,300	29,000	$9,580 r/	$330	31,600	31,000	$10,600	$341
Florida	34,300	33,100	8,900	269	35,300	34,900	9,000	257
Indiana	17,000	17,000	4,700	276	W	W	W	280
Michigan	24,900	24,900	5,310	213	24,900	25,100	5,380	214
Mississippi	136,000	136,000	16,200	119	127,000	127,000	15,900	125
Pennsylvania	46,800	46,800	8,770	188	49,600	49,600	8,270	166
Other 3/	442,000	442,000	94,600 r/	214	446,000	447,000	98,900	221
Total or average	731,000	729,000	148,000	203	715,000	715,000	148,000	207

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits, except average value; may not add to totals shown.
2/ Average value based on unrounded data and rounded to nearest dollar.
3/ Includes Alabama, Arizona, Arkansas, Colorado, Georgia, Idaho, Illinois, Kansas, Kentucky, Maine, Massachusetts, Minnesota, Missouri, Nevada, New Jersey, North Carolina, Ohio, Oklahoma, Oregon, Tennessee, Texas, Utah, Virginia, Wisconsin, and Wyoming.

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TABLE 3
EXPANDED PERLITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	1999 Average value per ton 2/	2000 Quantity (metric tons)	2000 Value (thousands)	2000 Average value per ton 2/
Concrete aggregate	4,330	$1,230	$284	2,200	$700	$318
Fillers	53,200	19,700	370	48,800	19,600	402
Filter aid	60,000	19,200	319	60,300	19,400	322
Formed products 3/	499,000	73,000	146	477,000	68,800	144
Horticultural aggregate	70,700	23,100	326	83,700	26,600	318
Laundries	4,070	1,080	266	3,360	933	277
Low-temperature insulation	2,850	1,100	386	2,160	886	410
Masonry and cavity-fill insulation	7,500	2,800	373	7,730	3,100	401
Plaster aggregate	13,700	2,430	177	7,040	2,110	300
Other 4/	17,300	5,570	322	22,400	5,930	267
Total or average	729,000	148,000	203	715,000	148,000	207

1/ Data are rounded to no more than three significant digits, except average value; may not add to totals shown.
2/ Average value based on unrounded data and rounded to nearest dollar.
3/ Includes acoustic ceiling panels, pipe insulation, roof insulation board, and unspecified formed products.
4/ Includes explosives, high-temperature insulation, paint, refractory, soap, steel, sugar manufacture, and various nonspecified industrial uses.

TABLE 4
PERLITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Armenia e/	6,000	6,000	35,000	35,000	35,000
Australia e/ 4/	5,000	5,000	5,000	5,000	5,000
Greece (screened)	417,882	500,117	425,000 e/	500,000	500,000
Hungary e/ 4/	110,000	120,000	130,000	148,000 r/	150,000
Iran	6,000 e/	10,000 r/ e/	13,320 r/	15,069 r/	15,000
Italy e/	60,000	60,000	60,000	60,000	60,000
Japan e/	304,000 r/	290,000 r/	251,000 r/	260,000 r/ e/	250,000
Mexico 4/	37,417	51,758	54,840	61,596 r/	67,001 5/
Philippines	20,000 e/	20,000 e/	6,356 r/	10,265 r/ 5/	10,000
Slovakia	25,160	25,000 e/	24,200 r/ e/	19,465 r/	20,000
South Africa	682	403	400 e/	400 e/	400
Turkey 4/	157,580	103,416	124,312	130,000	130,000
United States (processed ore sold and used by producers)	684,000	706,000	685,000	711,000 5/	672,000
Total	1,830,000 r/	1,900,000 r/	1,820,000 r/	1,960,000 r/	1,910,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Unless otherwise stated, figures represent processed ore output. Table contains data available through May 19, 2001.
3/ In addition to the countries listed, Algeria, Bulgaria, China, Iceland, Mozambique, and the former Yugoslavia are believed to have produced perlite but output was not reported, and available information is inadequate for the formulation of reliable estimates of output levels.
4/ Crude ore.
5/ Reported figure.

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PHOSPHATE ROCK

By Stephen M. Jasinski

Domestic survey data and tables were prepared by Christopher H. Lindsay, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Phosphorus is an essential element for plant and animal nutrition. Phosphorus is consumed primarily as a principal component of nitrogen-phosphorus-potassium (NPK) fertilizers that are used to enhance the growth of food crops throughout the world. Phosphate rock minerals are the only significant global resources of phosphorus.

The United States is the world's leading producer and consumer of phosphate rock and phosphate fertilizers. Domestic production decreased for the second consecutive year owing to the closure of two mines and lower production rates at several others. Mines in Florida and North Carolina accounted for 86% of domestic marketable production, with the remainder produced in Idaho and Utah. More than 90% of the phosphate rock mined was used to produce chemical fertilizers and animal feed supplements; the remainder was used to produce elemental phosphorus (P_4) and other industrial phosphates. Two companies in Idaho produced P_4 for downstream industrial compounds.

Domestic consumption and sales of marketable phosphate rock decreased by 10% from that of 1999. Manufacturers of phosphate fertilizers continued to be affected by weak export sales, primarily to China and India, which have been the major destinations for U.S. fertilizer exports for the past decade. In response to market conditions, several phosphoric acid plants were closed temporarily during the year, resulting in a drop in consumption of phosphate rock. Imports of phosphate rock were down by 11% after reaching a record high in 1999. The U.S. Census Bureau reported that wet process phosphoric acid (WPPA) production was 11.4 million metric tons (Mt) as available phosphorus pentoxide (P_2O_5) compared with 12.2 Mt in 1999 (U.S. Census Bureau, 2001). U.S. producers accounted for nearly 40% of world trade in converted phosphate products (Demetriou, 2001, p. 7). The major fertilizer products were diammonium phosphate (DAP), monoammonium phosphate (MAP), triple superphosphate (TSP), and WPPA.

Legislation and Government Programs

The U.S. Drug Enforcement Administration (DEA) proposed classifying red phosphorus, yellow phosphorus, and hypophosphorous acid as controlled substances or List I chemicals because they have been identified as being important chemicals for the illicit manufacturing of methamphetamine. Handlers of List I chemicals are subject to the Controlled Substances Act regulatory controls including registration, recordkeeping, reporting, and import/export requirements. The DEA determined that these controls are necessary to prevent the diversion of these chemicals to drug laboratories. The agency did not propose a threshold limit for reporting because there are few legitimate uses for the compounds, and only small quantities of the substances are required to manufacture methamphetamine. Industrial uses of red phosphorus include pyrotechnics, matches, incendiary shells, tracer bullets, and other phosphorus compounds. Red phosphorus and

Phosphate Rock in the 20th Century

In 1900, the United States was the largest producer of phosphate rock in the world, accounting for 48% of world production of 3.15 million metric tons. By that time, Florida had become the dominant producing State surpassing South Carolina, where phosphate rock was first discovered and mined in the United States in 1867. At this time, mining had begun shifting from river dredging to exploitation of hard rock and land-pebble deposits. Mining was accomplished by horse- and mule-drawn scrapers, pick and shovel, and in a few instances, steam shovels. By 1904, manual methods had been replaced by electric shovels to remove the overburden, and hydraulic pumps were used to move matrix to the washer plant. The implementation of the dragline in 1920 greatly improved efficiency by reducing labor and increasing the quantity of ore mined. In 1928, the flotation process was patented enabling companies to recover up to 95% of the phosphate that was previously discarded. Phosphate rock mining began in the Western United States in 1907 and in North Carolina in 1966. Phosphate rock production capacity doubled from 1960 to 1970 in response to increased demand for fertilizer and the shift to multinutrient, high-analysis fertilizers. Throughout the 20th century, fertilizer production was the major use of phosphate rock. Elemental phosphorus production and industrial applications never achieved more than 10% of total domestic usage.

In 2000, the United States remained the largest producer of phosphate rock in the world, accounting for nearly 29% of total world production of 133 million tons, and was the largest consumer of phosphate rock and largest exporter of phosphate fertilizers. Florida remained the largest producing State, followed by North Carolina, Idaho, and Utah. The United States was a major world supplier of phosphate rock until the early 1990s when producers shifted emphasis to exporting higher value fertilizer materials.

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hypophosphorous acid are derivatives of P_4 and the DEA estimates that only 2% of the P_4 produced domestically is converted into a form that will be subject to the regulation (U.S. Department of Justice, 2000).

Production

Domestic phosphate rock production data were developed by the U.S. Geological Survey from monthly and semiannual voluntary surveys of producers of phosphate rock. All companies responded to the canvass.

Phosphate rock production decreased for the second consecutive year, reaching its lowest point since 1993 (tables 1, 3). The phosphate industry was affected by a significant drop in export sales of DAP, the largest volume fertilizer product, and of phosphoric acid. Marketable output from Florida and North Carolina was down by 4%, owing to the closure of one mine in late 1999 and another in August 2000. Overall, production rates at the other mines were nearly the same as in 1999; consumption, however, dropped by 10%, and therefore stocks increased substantially. In Idaho and Utah, production declined by 10% owing to the combined effects of a temporary closure of one mine, stock depletion, and seasonal demand fluctuation. U.S. mine production was at 86% of rated annual capacity (table 13).

Southern States.—In Florida, phosphate rock was mined and processed by five companies: Agrifos, L.L.C.; Cargill Fertilizer, Inc.; CF Industries, Inc.; IMC Phosphates MP, Inc.; and PCS Phosphate Co., Inc. Their mines and plants were located in Hamilton, Hardee, Hillsborough, and Polk Counties (table 2). The Nu-Gulf Industries, Inc., Wingate Creek Mine in Manatee County was closed for the entire year. U.S. Agri-Chemicals Corp. and Farmland Hydro L.P., a joint venture between Farmland Industries, Inc., and Norsk Hydro ASA, operated WPPA and ammonium phosphate plants at Fort Meade and Green Bay, respectively, using phosphate rock purchased from other companies in Florida.

In December, Farmland-Hydro L.P. submitted a permit application to open a 6,114-hectare (ha) phosphate rock mine in Hardee County. According to the company, planned production will be 2.7 million metric tons per year (Mt/yr) for 30 years. A beneficiation plant will be built onsite, and the phosphate rock will be sent by rail to the Fort Meade WPPA facility in Polk County. Under Florida's ecosystem management team permitting process, the consolidated development application (CDA) is filed simultaneously with all appropriate Federal, State, and local agencies after the company conducts meetings with all interested parties. The application requires the demonstration of a net benefit to the environment in the form of the reclamation plan that restores a greater area of land than is disturbed. The firm anticipates receiving the permit by the end of 2001 (Green Markets, 2001b).

In May, IMC Phosphates filed a CDA for its proposed Ona Mine in Hardee County. The mine would encompass 8,335 ha, of which 24% of the area would not be disturbed. Total minable reserves are estimated to be 150 Mt. According to IMC, during the first 8 years of operation, it plans to mine 2.72 Mt/yr, and for the balance of the 24-year life of the facility, it will mine 5.45 Mt/yr. For each hectare of wetlands disturbed, it will create an average of 1.6 ha. Approval was anticipated by the end of 2001. IMC expected to submit a CDA for the proposed Pine Level Mine in DeSoto County in 2001 or 2002 (Green Markets, 2000d).

Agrifos closed its Nichols Mine in August in response to economic conditions, according to the company. Prior to the closure, production was limited because of excess water in the mine. Nichols was one of the smallest phosphate rock mines in Florida, with a production capacity of 1.1 Mt/yr. No decision had been made on whether the mine and its reserves would be sold. The Agrifos Fertilizer, LLC, plant in Pasadena, TX, would not be affected by the closure; it would rely exclusively on imported rock. Duke Energy Corp. acquired a financial interest in Agrifos, and Duke's wholly owned subsidiary, Duke Energy Merchants, L.L.C., will assume product sales and raw material purchasing responsibilities for the Pasadena facility (Green Markets, 2000e).

Mulberry Corp., the parent company of Mulberry Phosphates, Inc., Piney Point Phosphates, Inc., and Nu-Gulf Industries, ceased operations at all facilities in 1999, all of which remained closed in 2000. In December, the Florida Department of Environmental Protection (FDEP) sought to suspend the company's operating permits for its two processed phosphate plants because of failure to comply with orders to correct groundwater contamination (Green Markets, 2000b). In early 2001, Mulberry filed for chapter 11 bankruptcy protection and abandoned its facilities. The FDEP was then forced to maintain the Mulberry and Piney Point plants after Mulberry could not pay its electric bill. Although the plants had been closed for more than a year, electric pumps circulated water continuously through the phosphogypsum stacks. If the power were turned off, the acidic water could overflow into nearby waterways (Green Markets, 2001c).

Six concentrated phosphate plants were located along the Gulf of Mexico. IMC Phosphates operated a phosphoric acid plant at Uncle Sam, LA, using phosphate rock from the firm's mines in Florida and a DAP/MAP granulation facility at Faustina, LA. Both plants were closed for several months between January and October and then closed indefinitely in November owing to market conditions. The company's Taft, LA, DAP granulation facility and the Faustina phosphoric acid plant were closed for the entire year (IMC Global Inc., 2000, p. 3). The PCS Nitrogen Inc. plant in Geismar, LA, and Mississippi Phosphates Corp. plant in Pascagoula, MS, both used phosphate rock imported from Morocco. The Agrifos plant in Pasadena, TX, used both phosphate from the company's Nichols Mine in Florida and imports from Morocco.

Idaho and Utah.—In Idaho, four companies conducted open pit mining in Caribou County (table 2). Astaris L.L.C. operated the Dry Valley Mine on Federal and private leases, to provide feedstock for P_4 production at its Pocatello plant. Monsanto Co. operated the Enoch Valley Mine, which supplied its P_4 plant in Soda Springs. Agrium Inc. produced phosphate rock from the Rasmussen Ridge Mine to feed its Conda WPPA and DAP plants. J.R. Simplot Co. operated the Smoky Canyon Mine,

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which supplied its WPPA plant in Pocatello, by a 138-kilometer (km) slurry pipeline.

In October, Agrium was forced to close its phosphoric acid plant after a wall of a digester tank collapsed, which resulted in the spill of phosphoric acid and rock slurry. The plant was reopened in December at 80% capacity. The tank was scheduled for replacement in 2001 as part of the Agrium-Astaris joint-venture project to produce purified phosphoric acid, which will increase annual WPPA production capacity at the plant to 375,000 metric tons per year (t/yr) from 280,000 t/yr P_2O_5 (Agrium Inc., 2001, p. 23).

Astaris began implementation of an emission reduction program and site modifications to its Pocatello facility that were mandated by the U.S. Environmental Protection Agency in 1999 for violations of the clean air and water regulations (Green Markets, 2000c). In September, Astaris announced plans to reduce P_4 production by closing two of the four electric furnaces at its Pocatello, ID, plant in 2002. The company cited market conditions and the construction of a new purified phosphoric acid plant, which would be operated by Agrium and Astaris, as reasons for the closure (Green Markets, 2000a). In April 2001, Astaris accelerated its closure plan and reduced operations to one furnace in response to the rising cost of electricity (Green Markets, 2001a).

In Utah, SF Phosphates Ltd., Co., a joint venture between Simplot and Farmland Industries, Inc., operated a major mining and phosphate rock beneficiation facility near Vernal. The beneficiated phosphate rock was transported by slurry pipeline 155 km to the company's phosphate fertilizer production plant at Rock Springs, WY.

Universal Chemical Corp. continued in its efforts to obtain financing to open a phosphate rock conversion facility in eastern Utah. The company plans to use phosphate rock from the Ashley Valley Phosphate Co. deposit that is located near Vernal. Universal plans to process the phosphate ore with a method that was developed in Europe but never used in North America. Unlike conventional phosphoric acid production, which uses sulfuric acid to digest the rock, the rock would be treated with a weak hydrochloric acid solution onsite, which readily separates the silica, clay, and other impurities from the phosphate. The resulting phosphate-calcium solution would be transported by pipeline 71 km to the plant and the remaining inert material would be used for mine reclamation. The phosphate solution would be used to produce dicalcium and monocalcium phosphate for animal feed supplements and phosphoric acid. The byproduct calcium chloride could be reacted with sulfuric acid to manufacture food-grade gypsum. The State of Utah received a Federal grant of $870,000 to study the extension of a railroad line from the site of the proposed plant in Bonanza to connect with an existing rail line at Rifle, CO. The State has been working for more than 2 years on an economic development proposal that includes the 1,370-ha phosphate mine, a phosphate processing facility, a gypsum wallboard plant, a fertilizer plant, administration offices, and the 82-km short-line railroad. As of December 31, the company was in the process of obtaining financing for the project (Green Markets, 2000f).

Consumption

In 2000, apparent consumption was at its lowest level since 1993, and reported phosphate rock sold or used was at the lowest point since 1971 (table 4). Both decreased by 10% from that of 1999 owing to a drop in phosphoric acid production (U.S. Census Bureau, 2001). The weak market conditions that began in 1999 continued throughout 2000, with domestic producers exporting less to China and India because of increased competition, lower demand, new plants opening in the region, and high world inventories. Several fertilizer manufacturers in the Southern States temporarily closed production facilities in response to the significant decrease in DAP export sales. The major fertilizer producers in the South rely on exports for the bulk of their business, because the domestic market is mature and normally fluctuates very little from year to year. Domestic consumption of P_2O_5 contained in fertilizer increased slightly for the crop year ending June 30 (Terry and Kirby, 2001, p. 6).

Phosphate rock used in the Western United States fell slightly because of the temporary closure of the Agrium plant, which resulted in a concurrent drop in rock production and seasonal fertilizer demand fluctuations. Western fertilizer manufacturers only sold their products domestically and were not affected by the world market situation. The only two P_4 plants in the Western Hemisphere are located in Idaho. Approximately 65% of P_4 was consumed to manufacture thermal phosphoric acid, which was used directly in detergents, food additives, water- and metal-treatment chemicals, and soft drinks, and as a raw material to make calcium, potassium, and sodium phosphates. The other 35% of P_4 was used directly to manufacture phosphorus trichloride, pentasulfide, and other compounds that were used in herbicides, insecticides, flame-retardants, lubrication greases, and plasticizers. Production of thermal phosphoric acid was 283,000 metric tons (t) of P_2O_5 compared with 259,000 t in 1999 (U.S. Census Bureau, 2001). Exports of P_4 fell to 3,440 t from 5,740 t in 1999 (table 11).

Purified wet-process phosphoric acid (PWA), which is less costly to produce than thermal acid, had attained a greater market share than thermal acid as a raw material for industrial phosphorus derivatives (Hume and others, 2000). PWA can be used to produce most phosphorus compounds except phosphorus pentasulfide and phosphorus trichloride, which is used to make herbicides, pesticides, and flame-retardants. U.S. P_4 production capacity was expected to drop to about 150,000 t/yr in 2001 from 236,000 t/yr to with the closure of three of the four furnaces at the Astaris plant in Pocatello, ID. Astaris will then begin producing PWA at a new 80,000 t/yr facility it will operate with Agrium at Soda Springs, ID (Green Markets, 2000a).

Stocks

U.S. stocks of phosphate rock ended the year 18% higher than in 1999 owing to the temporary closure of several phosphoric acid plants in Florida and Louisiana. Mine production continued on a regular schedule in anticipation of building stock

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when the plants eventually reopen. By region, stocks increased by 27% in Florida and North Carolina and dropped by 10% in Idaho and Utah (table 3).

Transportation

In Florida, beneficiated phosphate rock was moved by rail and truck to phosphoric acid plants within the State. Phosphate rock, phosphate acid, fertilizers, and animal feed supplements were sent by rail or truck to the port of Tampa and then were shipped for domestic use or export. More than 22 Mt/yr of phosphate-related materials move through the port of Tampa, representing nearly 50% of total tonnage handled at the port (Tampa Port Authority, 2000, Bulk cargo, accessed April 3, 2001, at URL http://www.tampaport.com/bulkcargo.htm).

Phosphate fertilizers produced by companies along the Gulf of Mexico were transported primarily by barge on the Mississippi River and its tributaries, by rail, and by truck for domestic consumption. Exported products were shipped directly from major ports along the Gulf of Mexico. PCS Phosphates operated a port facility at Morehead City, NC, for export and import. Phosphates produced at its Florida facilities were sent by rail to Morehead City. In the West, phosphate ore was sent from the mine via truck, rail, and slurry pipeline to production facilities.

Prices

The average price for domestic phosphate rock decreased by 21% in 2000 (table 5).

Foreign Trade

Imports of phosphate rock were estimated to be 1.93 Mt, an 11% decrease from that of 1999. Reported imports from the U.S. Census Bureau were 665,000 t because some data were suppressed (table 12). More than 99% of all imported phosphate rock was from Morocco and primarily used by three companies: Agrifos, Mississippi Phosphates, and PCS Nitrogen.

Phosphate rock exports increased by 10% to 299,000 t (table 6). Domestic exports of DAP, the major phosphate fertilizer product, dropped by 27% compared with 1999 because of reduced purchases by China and India. Exports of DAP to India were down by 85% from the previous year owing to large inventories, government subsidy programs that encourage purchasing from Indian companies, and lower demand. The Oswal Chemicals and Fertilizers Ltd. 1.5-Mt/yr DAP plant began production early in the year; however, it never achieved full operating capacity because of phosphate rock supply problems (Fertilizer International, 2000c). The IndoGulf Corp. 400,000-t/yr DAP plant was commissioned in September and, unlike Owsal, the facility used imported WPPA (Fertilizer International, 2000b). Neither plant had a significant impact on trade. China imported 11% less DAP from the United States because of lower demand, high inventory, and increased internal production. Phosphoric acid and concentrated superphosphate exports also decreased, while MAP exports increased by 28% (tables 7-10). Overall, the United States accounted for 40% of total world trade in processed phosphates. By product, DAP accounted for 61% of the total world trade, followed by MAP with 25% and TSP with 14% (Demetriou, 2001, p. 7).

World Review

World production was estimated to have decreased to 133 Mt from 137 Mt in 1999 (table 14). The United States, Morocco, China, and Russia accounted for 65% of total production, by order of output. In addition to lower production, worldwide shipments of phosphate rock decreased for both export and internal consumption, while stocks increased (Demetriou, 2001, p. 6). The closure of two phosphoric acid plants in the Netherlands and the opening of a phosphate rock mine in Canada reduced trade in phosphate rock in Europe and North America. In Asia, such traditional suppliers as Jordan, Morocco, and Togo faced increased competition from China. World consumption of phosphate rock, which closely mirrors production, was estimated to have fallen slightly. Consumption of P_2O_5 for fertilizer increased slightly (Prud'homme and Soh, 2000). New fertilizer plants in Australia and India, which began operation in late 1999, had difficulties achieving full operating capacity but apparently corrected problems by the end of the year.

Australia.—WMC Fertilizers Pty. Ltd. started production at its Queensland Mine, which supplied its nearby fertilizer plant complex. The mine has a rated capacity of 2.2 Mt/yr and demonstrated reserves of 100 Mt. The mine was expected to be operating at full capacity in 2001, after two major problems were corrected with the fertilizer plant. Early in the year, the phosphoric acid plant experienced problems with the agitator blades in two reactors, and then the entire ammonia plant was closed for several extended periods for retooling. By October, the facility was operating at 60% of annual production capacity (WMC Ltd., 2001).

China. — Spur Ventures, Inc., released the results of a feasibility study of the Yichang phosphate project in central China. The project consists of five phosphate rock deposits containing 579 Mt of reserves averaging 21.2% P_2O_5. The company proposes to vertically integrate mining and fertilizer production to manufacture high-analysis fertilizers. Anticipated mine production will be 1.25 Mt/yr of phosphate concentrate. A 126-km long, 22-centimeter diameter pipeline was proposed to be built to transport the concentrate to the chemical plant near the Yangtze River. The fertilizer plant would produce either NPK compounds or DAP. Initial capacity would be 480,000 t/yr DAP and 529,000 t/yr NPK. Total estimated cost of the project was $371 million (He, 2000).

The Phosphate Chemicals Export Association, Inc. (PhosChem) signed a 2-year extension to its existing DAP supply contract with China National Chemicals Import and Export Corp. (Sinochem). The new pact would run through December 31, 2002, and under the terms of the agreement, Sinochem would purchase unspecified monthly shipments with an option to purchase additional tonnage (Phosphate Chemical

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Export Association, Inc., 2000).

Cargill was planning to assist the Yunnan Phosphate Fertilizer Factory in upgrading its phosphoric acid plant and adding a DAP granulation facility with a capacity of 600,000 t/yr. Each company would contribute $15 million to the project. Yunnan Province had about 20% of the country's phosphate rock reserves, but only about 10% to 15% was considered suitable for WPPA production (Fertilizer Markets, 2000a).

The U.S. Trade Representative negotiated a United States-China fertilizer trade agreement in April that would become effective with China's accession into the World Trade Organization (WTO). The agreement established a tariff rate quota for certain fertilizers and expanded the opportunities for direct sales and distribution by foreign companies in China. The agreement set a quantity subject to a quota tariff of 4% and any tonnage above the amount would be subject to a 50% tariff. The DAP quota would start with a tonnage of 5.5 Mt and increase gradually to 6.9 Mt over 6 years. The Chinese Government would have to set the quota by January 1 of each year and could not revise it during the year.

The other provision, which would take effect after 5 years, would allow free trade in fertilizers within China by foreign-owned companies. Prior to the agreement, companies were required to enter into joint-venture agreements with Chinese companies and could not be the majority partner (The Fertilizer Institute, 2000).

Guinea-Bissau.—The Federal Government formalized mining leases on the Champion Resources, Inc., Farim phosphate rock deposit. The leases would be valid for 25 years and automatically renewable for another 25 years. Champion released the results of the final mine plan study. The report indicated recoverable reserves of 166.2 Mt of phosphate ore grading 29.8% P_2O_5, a 58% increase in tonnage from initial tests conducted in 1999. The initial 15-year mine plan anticipated a production rate of 2.47 Mt/yr of 31% P_2O_5 concentrate, which would be upgraded to 32% to 34% P_2O_5. Champion must still finalize financing agreements for the project (Fertilizer International, 2000a).

Jordan.—Norsk Hydro decided against entering into a joint venture with Jordan Phosphate Mines Co. (JPMC) to build a 440,000-t/yr phosphoric acid plant near the JPMC Eshidiya Mine and two 627,000-t/yr DAP/NPK plants at Aqaba. Hydro cited that it had given higher priory to other projects; the rise in worldwide P_2O_5 capacity, low DAP prices, and Indian subsidy programs that limit imports, however, were believed to have influenced the decision. The project was to be part of the JPMC long-term plan to gradually increase mine production at Eshidiya while decreasing production at its other two mines. Financing for the construction of a rail line from Eshidiya to Aqaba was being reevaluated because it would have been primarily for this project. JPMC had not announced whether another partner would be sought or if it would attempt to finance the project independently (Fertilizer Markets, 2000b).

Saudi Arabia.—Saudi Arabian Mining Co. approved development of the Al Jalamid phosphate project in the northwestern part of the country. The project would consist of a mine and DAP plant, focusing on the export market. The Al Jalamid deposit had proven reserves of 216 Mt, with an average grade of 32.5% P_2O_5. Based on an average mine output of 4.3 Mt/yr, the deposit could be mined for more than 50 years. The proposed DAP plant would have an annual capacity of 2 to 4 Mt/yr, although initial capacity would be around 1 Mt/yr and would be adjusted to market conditions. The mine was located about 1,100 km from the port of Al Jubail and no transportation links existed between the mine and port. A rail line had been considered and other options were being evaluated. A five-part detailed mining study started in midyear and was expected to be completed in mid-2001. Construction would not begin until the third quarter of 2001 at the earliest (Fertilizer International, 2001).

Outlook

The short-term outlook for the domestic phosphate industry will depend upon how quickly exports of processed phosphates, primarily DAP, can return to the levels achieved prior to 2000. Phosphate rock production and consumption in the Florida-North Carolina region will likely be lower in 2001 because of the high inventories accumulated in 1999 and 2000 and the indefinite closure of two mines and several fertilizer plants during the same period. Output and demand in Idaho and Utah is expected to remain steady. The opening of a new PWA plant will offset the reduction in P_4 production capacity.

World production of phosphate rock, which has been on a downward trend for the past 2 years owing to reduced demand by fertilizer manufacturers, will begin to increase at about the same rate as fertilizer consumption. World demand for phosphate fertilizer is projected to grow at a rate of 2.3% per year over the next decade according to industry analysts. The ever-increasing world population and the need for adequate food supplies ensure the long-term growth for the industry. The largest demand growth will occur in China, India, and developing countries in Asia and Latin America. Nearly two-thirds of U.S. DAP export sales in recent years have been to China and India. Changes in world production and trade patterns, however, especially related to India, have affected U.S. producers significantly. The drop in exports in 2000 was attributed more to supply and demand issues than the effect of new DAP/MAP plants that have opened in Australia and India. The full impact of the new plants on world trade is expected to occur in late 2001 when they should be operating at near rated capacity. Future trade to India also will depend upon government subsidy programs that limit imports.

China has become the most important export market for domestic fertilizers. China has abundant phosphate rock reserves and is a major exporter, but it lacks fertilizer production capacity. Several phosphate fertilizer production facilities are set to open within 5 years, but imports will still be necessary for some time. As demonstrated in 2000, Chinese demand has been very inconsistent and has been affected by low grain prices, use of cheaper NPK compounds, an effort to limit imports, and high inventories. U.S. exports to China and India are expected to be less in 2001, but the potential for sales to China would improve if the country were accepted as a member

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of the WTO. Shipments of fertilizer to Latin American have increased but will not fully replace lost sales to India and China.

References Cited

Agrium Inc., 2001, 2000 annual report: Calgary, Canada, Agrium Inc., 70 p.

Demetriou, S.J., 2001, World outlook for phosphate fertilizer production, consumption, and trade, *in* Sulphur Phosphate Symposium, 18th, Amelia Island, FL, February 22, Proceedings: Washington, DC, The Sulphur Institute, DC, 30 p.

Fertilizer International, 2000a, Guinea-Bissau Government formalizes Farim mining licences: Fertilizer International, no. 378, September-October, p. 12.

———2000b, IndoGulf commissions Dahej DAP plant: Fertilizer International, no. 379, November-December, p. 10.

———2000c, Oswald and JPMC in rock quality dispute: Fertilizer International, no. 379, November-December, p. 6.

———2001, Al Jalamid on a fast track?: Fertilizer International, no. 380, January-February, p. 40-41.

Fertilizer Markets, 2000a, Cargill signs deal to make DAP in China: Fertilizer Markets, v. 11, no. 12, October 2, p. 2.

———2000b, Hydro pulls plug on phosphate plant: Fertilizer Markets, v. 11, no. 20, December 4, p. 2.

Green Markets, 2000a, Astaris plans revealed: Green Markets, v. 24, no. 38, September 18, p. 8-9.

———2000b, Florida moves to suspend Mulberry's operating permits: Green Markets, v. 24, no. 50, December 11, p. 1, 12.

———2000c, FMC to spend $190 million on plant cleanup: Green Markets, v. 24, no. 7, February 14, p. 9.

———2000d, IMCA files application for new Fla. mine: Green Markets, v. 24, no. 20, May 15, p. 8-9.

———2000e, Questions surround Agrifos' decision to close Nichols Mine in Florida: Green Markets, v. 24, no. 26, June 26, p. 1, 12.

———2000f, Universal says phosphate/gypsum process enviro-friendly: Green Markets, v. 24, no. 36, September 4, p. 8.

———2001a, Astaris to sell power back—Permanent job losses seen: Green Markets, v. 25, no. 13, March 26, p. 1, 12.

———2001b, Farmland submits application for new Florida mine: Green Markets, v. 25, no. 2, January 8, p. 8.

———2001c, Mulberry Phosphates abandons processing plants; officials scramble to avoid environmental problems: Green Markets, v. 25, no. 7, February 12, p. 1, 11-12.

He, Y.B I., 2000, Spur Ventures, Inc.—Feasibility study on Yichang phosphate project completed: Vancouver, Spur Ventures, Inc., press release, October 30, 2 p.

Hume, Claudia, Schmitt, Bill, and Alperowicz, Natasha, 2000, Phosphates new lineup: Chemical Week, August 2, p. 20-27.

IMC Global Inc., 2001, Form 10-K—Fiscal year 2000: Securities and Exchange Commission, 18 p.

Phosphate Chemicals Export Association, Inc., 2000, PhosChem and China's Sinochem agree to two-year extension of sales accord through 2002: Phosphate Chemicals Export Association, Inc., press release, September 21, 2 p.

Prud'homme, Michel, and Soh, K.G., 2000, Short term prospects for world agriculture and fertilizer use, *in* IFA Enlarged Council Meeting, 26th, Rio de Janeiro, November 15-17, Proceedings: Paris, International Fertilizer Industry Association, document A/00/135, 29 p.

Terry, D.L., and Kirby, B.J., 2001, Commercial fertilizers 2000: Lexington, KY, Association of American Plant Food Control Officials, 41 p.

The Fertilizer Institute, 2000, Fertilizer industry lauds new China WTO fertilizer agreement: Washington, DC, The Fertilizer Institute press release, May 19, 3 p.

U.S. Census Bureau, 2001, Inorganic fertilizer materials and related products—Fourth quarter 2000: U.S. Census Bureau, MQ325B(00)-4, March, 5 p.

U.S. Department of Justice, Drug Enforcement Administration, 2000, Control of red phosphorus, white phosphorus, and hypophosphorous acid (and its salts) as List I chemicals: Federal Register, v. 65, no. 186, September 25, p. 57577-57581.

WMC Ltd., 2001, Annual report 2000: Southbank, Australia, WMC Ltd., 50 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Fertilizers—Sustaining Global Food Supplies. Fact Sheet FS-155-99, 1999.

Phosphate. International Strategic Minerals Inventory Summary Report, Circular 930-C, 1984.

Phosphate Deposits. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Phosphate Rock. Ch. in Mineral Commodity Summaries, annual.

Phosphate Rock. Mineral Industry Surveys, monthly.

Phosphate Rock. Minerals Industry Surveys, crop year.

Sedimentary Phosphate Resource Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey. Circular 888, 1982.

Other

Fertilizer International (London), bimonthly.

Fertilizer Markets, weekly.

Fertilizer Week (London), weekly.

Green Markets, weekly.

Industrial Minerals (London), monthly.

Inorganic Fertilizer Materials. U.S. Census Bureau, quarterly and annual.

International Fertilizer Development Center, Muscle Shoals, AL.

International Fertilizer Industry Association, Paris, France.

Office Chérifien des Phosphates, Casablanca, Morocco.

Phosphate Availability and Supply—A Minerals Availability Appraisal. U.S. Bureau of Mines Information Circular 9187, 1988.

The Fertilizer Institute, Washington, DC.

U.S. Department of Agriculture, Economic Research Service, Washington, DC.

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TABLE 1
SALIENT PHOSPHATE ROCK STATISTICS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Mine production (crude ore)	179,000	166,000	170,000	161,000	163,000
Marketable production:	45,400	45,900	44,200	40,600	38,600
P_2O_5 content	13,300	13,300	12,900	11,800	11,200
Value	$1,060,000	$1,080,000	$1,130,000	$1,240,000	$932,000
Average 2/ dollars per metric ton	$23.40	$24.40	$25.46	$30.56	$24.14
Sold or used by producers: 3/	43,500	42,100	43,700	41,600	37,400
P_2O_5 content	12,900	12,200	12,700	12,100	10,900
Value 4/	$1,020,000	$1,030,000	$1,130,000	$1,310,000	$909,000
Average dollars per metric ton	$23.40	$24.50	$25.87	$31.49	$24.29
Exports:	1,570	335	378	272	299
Value	$56,200	$11,700	$16,100	$11,400	$12,100
Average dollars per metric ton	$35.82	$34.80	$42.70	$41.96	$40.38
Imports for consumption e/ 5/	1,800	1,830	1,760	2,170	1,930
C.i.f. value e/	$104,000	$91,800	$92,700	$123,000	$99,800
Average dollars per metric ton	$57.91	$50.19	$52.66	$56.54	$51.75
Consumption e/ 6/	43,700	43,600	45,000	43,500	39,000
Stocks, December 31, producers	6,390	7,910	7,920	6,920	8,170
World, production, gross weight	135,000	143,000	144,000	137,000 r/	133,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except average values.

2/ Average value based on the sold or used values.

3/ Includes domestic sales and exports.

4/ Total value of all domestic and export sales.

5/ Includes some estimated phosphate rock tonnage imported from Morocco not reported by the U.S. Census Bureau.

6/ Expressed as sold or used plus imports minus exports.

TABLE 2
ACTIVE PHOSPHATE ROCK MINES IN THE UNITED STATES IN 2000

Owner	Mine	County and State
Agrifos, L.L.C.	Nichols 1/	Polk, FL.
Agrium Inc.	Rasmussen Ridge	Caribou, ID.
Astaris, L.L.C.	Dry Valley	Do.
Cargill Fertilizer, Inc.	Hookers Prairie	Polk, FL.
Do.	South Fort Meade	Do.
CF Industries, Inc.	South Pasture	Hardee, FL.
IMC Phosphates MP Inc.	Four Corners	Hillsborough, FL.
Do.	Fort Green	Polk, FL.
Do.	Hopewell	Hillsborough, FL.
Do.	Kingsford	Polk/Hillsborough, FL.
Monsanto Co.	Enoch Valley	Caribou, ID.
PCS Phosphate Co., Inc.	Swift Creek	Hamilton, FL.
Do.	Aurora	Beaufort, NC.
SF Phosphates, Ltd. Co.	Little Brush Creek	Uintah, UT.
J.R. Simplot Co.	Smoky Canyon	Caribou, ID.

1/ Ceased operations in August 2000.

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TABLE 3
PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES, BY REGION 1/

(Thousand metric tons and thousand dollars)

Period/region	Mine production (crude ore)		Marketable production			
			Beneficiated			Ending stocks, rock
	Rock	P_2O_5 content	Rock	P_2O_5 content	Value 2/	
1999	161,000	15,900	40,600	11,800	1,240,000	6,920
2000:						
January-June:						
Florida and North Carolina	79,900	7,430	17,400	5,100	421,000	6,440
Idaho and Utah	3,680	797	2,740	796	70,900	1,620
Total	83,600	8,220	20,100	5,890	492,000	8,060
July-December:						
Florida and North Carolina	75,100	6,810	15,900	4,640	384,000	6,620
Idaho and Utah	3,880	873	2,560	717	57,000	1,550
Total	78,900	7,680	18,500	5,350	441,000	8,170
Grand total	163,000	15,900	38,600	11,200	932,000	XX

XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Average value based on the sold or used values.

TABLE 4
PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GRADE AND REGION 1/

(Thousand metric tons and thousand dollars)

Period and grade (percentage of BPL content 2/)	Rock	P_2O_5 content	Value 3/
1999	41,600	12,100	1,310,000
2000:			
January-June:			
60 to less than 66	17,400	5,100	425,000
Other 4/	1,670	482	38,300
Total	19,100	5,580	464,000
July-December:			
60 to less than 66	15,600	4,560	380,000
Other 4/	2,710	725	65,400
Total	18,400	5,280	445,000
Grand total	37,400	10,900	909,000
Florida and North Carolina	31,900	9,340	774,000
Idaho and Utah	5,470	1,520	134,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ 1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
3/ F.o.b. mine.
4/ Includes less than 60% and greater than 66% BPL content.

TABLE 5
VALUE OF U.S. PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL content 1/)	1999			2000		
	Domestic	Export	Average	Domestic	Export	Average
70 to less than 72	W	W	W	W	W	W
66 to less than 70	31.27	W	31.36	30.06	W	30.06
60 to less than 66	30.08	W	32.03	24.27	W	24.36
Weighted average 2/	30.56	41.96	31.49	24.20	40.38	24.29

W Withheld to avoid disclosing company proprietary data.
1/ 1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
2/ Includes less than 60%, and greater than 72%, in addition to the grades listed.

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TABLE 6
U.S. EXPORTS OF GROUND AND UNGROUND PHOSPHATE ROCK 1/

(Thousand metric tons)

Country	1999	2000
Canada	37	33
Netherlands	160	181
Other	75 r/	85
Total	272	299

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF SUPERPHOSPHATES (CONCENTRATED)

(Thousand metric tons)

Country	1999	2000
Argentina	8	16
Australia	205	110
Bangladesh	123	18
Brazil	82	162
Canada	10	6
Chile	62	67
Japan	52	51
Peru	8	10
Uruguay	5	2
Other	79	103
Total	634	545

Source: U.S. Census Bureau.

TABLE 8
U.S. EXPORTS OF DIAMMONIUM PHOSPHATE 1/

(Thousand metric tons)

Country	1999	2000
Argentina	167	223
Australia	429	413
Brazil	16	120
Canada	102	109
China	4,580 r/	4,060
Colombia	78	97
Ecuador	62	42
India	2,340	345
Japan	334	356
Kenya	114	98
Mexico	256	295
Pakistan	355	295
Thailand	239	204
Other	787	577
Total	9,860 r/	7,240

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF
MONOAMMONIUM PHOSPHATE 1/

(Thousand metric tons)

Country	1999	2000
Australia	432	491
Brazil	306	283
Canada	514	861
Chile	26	8
Colombia	105	108
Guatemala	34	43
Japan	123	127
Mexico	77	52
Thailand	25	16
Other	147	307
Total	1,790	2,300

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 10
U.S. EXPORTS OF PHOSPHORIC ACID 1/

(Thousand metric tons)

Country	1999	2000
Australia	118	65
Canada	25	29
India	189	149
Other	67 r/	135
Total	399	378

r/ Revised.
1/ Excludes superphosphoric acid tonnage.

Source: U.S. Census Bureau.

TABLE 11
U.S. EXPORTS OF ELEMENTAL PHOSPHORUS 1/

	1999		2000	
Country	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Brazil	145	$218	5	$14
Canada	841	1,460	693	1,400
Japan	2,100	3,710	1,210	2,670
Korea, Republic of	154	292	--	--
Mexico	1,970	4,340	1,260	2,610
Netherlands	--	--	17	27
Other	531	1,060	262	504
Total	5,740	11,100	3,440	7,220

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ F.a.s. values.

Source: U.S. Census Bureau.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF PHOSPHATE ROCK AND PHOSPHATIC MATERIALS 1/

(Thousand metric tons and thousand dollars)

Phosphatic materials	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Natural calcium phosphates, unground 3/	92	4,150	186	5,750
Natural calcium phosphates, ground 3/	653	38,800	479	28,600
Total calcium phosphates 4/	2,170	123,000	1,930	99,800
Dicalcium phosphate	7	7,720	8	9,300
Elemental phosphorus	2	4,190	3	5,570
Normal superphosphate	(5/)	6	(5/)	9
Triple superphosphate	64	10,400	3	430
Diammonium phosphate	36	8,360	123	21,900
Fertilizer containing nitrates and phosphates	114	7,810	79	7,220
Phosphoric acid	1	251	(5/)	70

1/ Data are rounded to no more than three significant digits.
2/ Declared c.i.f values.
3/ Some phosphate rock tonnages and values were suppressed by the U.S. Census Bureau.
4/ Includes an estimate for data suppressed by U.S. Census Bureau.
5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 13
PHOSPHATE ROCK ANNUAL WORLD PRODUCTION CAPACITY, DECEMBER 31, 2000 1/

(Thousand metric tons)

Region/country	Capacity
United States	44,800
Africa	53,100
Asia	33,600
Europe and Russia	13,800
Middle East	14,600
Latin America and Canada	8,380
Oceania	3,400
Total	172,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Sources: International Fertilizer Industry Association and the U.S. Geological Survey.

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TABLE 14
PHOSPHATE ROCK, BASIC SLAG, AND GUANO: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Commodity and country	Gross weight					P2O5 content				
	1996	1997	1998	1999	2000 e/	1996	1997	1998	1999	2000 e/
Phosphate rock: 3/										
Albania e/	2	1	1	1	1	(4/)	(4/)	(4/)	(4/)	(4/)
Algeria	1,051	1,063	1,115	1,096 r/	875	320	330 e/	358 e/	340 r/ e/	265
Australia e/	1 5/	1	1	2	540	(4/) 5/	(4/)	(4/)	(4/)	150
Brazil	3,823	4,270	4,421	4,300 r/	4,900	1,353	1,500	1,560	1,528 r/	1,740
Chile	17	13	15	15 e/	15	5	3	4	4 e/	4
China e/	21,000	24,500	25,000	20,000 r/	19,400	6,300	7,530	7,500	6,000 r/	5,820
Christmas Island e/	600	600	600	600	575	198	198	198	198	190
Colombia	40	45	73 r/ e/	75 r/ e/	75	8	9	14 r/ e/	14 r/ e/	14
Egypt 6/	808	1,067 r/	1,076 r/	1,018 r/	1,020	222	310 r/	311 r/	298 r/	300
Finland	667	690	716	734 r/ e/	700	246	254	260	268 r/ e/	250
India	1,432	1,043	1,730	1,750 e/	1,720	387	282	467	473 e/	464
Indonesia	8 e/	1	1	1 r/	1	2 e/	(4/)	(4/)	(4/) r/	(4/)
Iraq e/ 6/	1,000	1,000	1,000	1,000	1,000	300	300	300	300	300
Israel	3,839	4,047	4,067 r/	4,128 r/	4,110	1,201	1,260 r/	1,288	1,310 r/	1,300
Jordan	5,355	5,896	5,925 r/	6,014 r/	5,506 5/	1,765	1,946 r/	1,955 r/	1,985 r/	1,817 5/
Kazakhstan e/	1,700	1,000	100	1,000 r/	1,000	500	290	29	290 r/	290
Korea, North e/	520	520	450	350	350	164	164	142	105	105
Mexico	682	714	756	951 r/	1,052 5/	205	214	227	285 r/	316 5/
Morocco 7/	20,855	23,084	23,587	22,767 r/	21,568 5/	6,552	7,848	7,850	7,500 r/	7,200
Nauru	510	491	487	600 e/	500	194	187	185	230 e/	195
Pakistan e/	10	11 5/	11	12	11	2	2	2	2	2
Peru	103	104	104	104 e/	104	32	32 e/	37	37 e/	37
Philippines e/	30	30	8 r/ 5/	105 r/ 5/	100	10	10	27 r/	35 r/	33
Russia e/	8,300 r/	9,800 r/	10,100 r/	11,400 r/	11,100	3,200 r/	3,800 r/	3,900 r/	4,400 r/	4,300
Senegal e/	1,340	1,570	1,480	1,800	1,800	478	575	540	630	630
South Africa	2,655	2,732	2,739	2,957 r/	2,778 5/	1,036	1,066	1,068	1,153 r/	1,080
Sri Lanka	34	30 r/	38 r/	32 r/	32	12	10	13 r/	11 r/	11
Syria	2,189	2,392	2,496	2,084 r/	2,166 5/	670	730	765	635 e/	658
Tanzania	28	3	2	2 e/	2	9	1	1	1 e/	1
Thailand	4	4	3	4	3 5/	1	1	1	1 r/	1
Togo	2,731	2,631	2,250	1,700 e/	1,370	980	955	812	610 e/	500
Tunisia	7,167	6,941	7,901	8,006 r/	8,339 5/	2,150	2,140	2,370	2,400 e/	2,500
United States	45,400	45,900	44,200	40,600	38,600 5/	13,300	13,300	12,900	11,800	11,200 5/
Uzbekistan e/	--	--	100	150	300	--	--	17	25	50
Venezuela	148	291	322	366 r/	375	40	79	87	99 r/	101
Vietnam e/	475	834	860	850	850	143	250	258	255	255
Zimbabwe, concentrate e/	123 5/	94	91	90	90	39	30	29	29	29
Total	135,000	143,000	144,000	137,000 r/	133,000	42,000 r/	45,600 r/	45,400 r/	43,200 r/	42,100
Basic (Thomas converter) slag: e/										
Egypt	8	8	8	8	8	2	2	2	2	2
France	77	44	45	50	50	14	8	8	8	8
Germany	125	125	125	150	150	19	19	19	19	18
Luxembourg	500	500	500	475	475	75	75	75	75	75
Total	710	677	678	683	683	110	104	104	104	103
Guano, Philippines e/	5	5	5	5	-- 5/	2	2	2	2	-- 5/

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 8, 2001. Data for major phosphate rock-producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

3/ In addition to the countries listed, Canada and Nigeria produced phosphate rock, but output is not reported quantitatively, and available information is inadequate for formulation of reliable estimates of output levels.

4/ Less than 1/2 unit.

5/ Reported figure.

6/ Beneficiated.

7/ Includes production from Western Sahara.

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PLATINUM-GROUP METALS

By Henry E. Hilliard

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2000, the average price of palladium, platinum, rhodium, and ruthenium increased by 90%, 45%, 120%, and 219%, respectively. The price increases for platinum and rhodium can be attributed to increased demand, mainly from the automobile sector. Palladium prices, for the third consecutive year, were influenced by unreliable imports from Russia. Russia accounted for 51% of U.S. palladium supply and 3% of U.S. platinum supply in 2000. Prices for the relatively unknown ruthenium increased sharply to to an average $129.76 per troy ounce in 2000 from $40.70 per ounce in 1999. Ruthenium prices were driven by increased demand from the electronics sector and reports of the development of new ruthenium-based superalloys for use in aerospace applications.

Higher prices were followed by an increase in the pace of exploration for PGM, and a growing number of joint ventures were signed in recognition of the strong fundamentals for these metals. Decreases in the price of PGM in the first part of 2000 did little to dampen enthusiasm for further exploration because of expected increases in demand from the automobile industry, jewelry manufacturing, and other industrial applications as well as limited supplies of the metals from Russia.

The automobile industry continued to be the major consumer of PGM. In 2000, autocatalysts accounted for approximately 98% of rhodium demand, 66% of palladium demand, and 41% of platinum demand. Despite the overall increase in vehicle sales in 2000, demand for palladium by auto manufacturers declined, as automakers and electronic component makers made concerted efforts to reduce the palladium content of their products. U.S. demand for platinum in jewelry manufacture, on the other hand, continued to grow and has become one of platinum's largest applications. Demand for platinum in the automobile industry increased in Europe due to higher loadings on catalysts in diesel automobiles. Diesels have been gaining substantial market share in Europe over the last several years. In the United States, a return to the use of more platinum in autocatalysts for cars powered by gasoline began in late 1999and gained momentum in 2000. This trend was expected to continue, especially if the price of palladium remained above that of platinum. Demand for platinum metal in the industrial sector continued to increase; demand was expected to be up by more than 3,000 kilograms (kg). Increased platinum use in computer hard disks caused demand in electrical-electronics applications to increase substantially.

Growth in consumer demand for iridium by the glass industry for crucibles was more than offset by lower demand for use in autocatalysts.

Platinum-Group Metals in the 20th Century

At the beginning of the 20th century, the use of PGM in the United States was limited to the manufacture of laboratory ware, as a catalyst in the production of sulfuric and nitric acids, and in jewelry. Almost all U.S. production of PGM at that time was from placer deposits in the Goodnews Bay district of southwestern Alaska and gold placers in California. In Canada, platinum was produced as a byproduct of nickel copper-copper mining. In 1920, a large primary platinum deposit was discovered by Hans Merensky in a platiniferous reef in South Africa in the Bushveld Igneous Complex.

After an active period of placer mining and prospecting for precious metals, exploration for PGM in the United States essentially ceased in the early 1900s because of the availability of foreign supplies and the lack of directly applicable modern geologic, geothermal, and geophysical techniques for finding new deposits. U.S. production was less than 800 kilograms per year while consumption was estimated at about 9,000 kilograms. In the mid 1960s, analytical techniques for determining PGM in geologic materials at the low parts-per-billion level were developed. With a better understanding of the geochemistry and geology of the elements, modern programs of exploration began to find previously unknown occurrences of PGM. The most promising occurrences were found in Stillwater, Sweet Grass, and Park Counties in southern Montana. In the early 1970s, geologists discovered palladium and platinum along the J-M Reef in Stillwater County. In 1979, a partnership was formed to develop PGM discovered in the area. In 1986, underground mining operations began at the Stillwater property.

By 2000, the fundamental structure of the markets for palladium, platinum, and the other PGM changed substantially. World production had increased to about 365,000 kilograms. South Africa, Russia, and Canada remained the world's major producers while the United States became a minor source, producing about 13,400 kilograms in 2000. PGM-based catalytic converters, developed in the mid-1950s, had become required equipment on all automobiles manufactured in the United States. Autocatalysts were, by a significant margin, the largest end-use of PGM in the country, accounting for about 48,000 kilograms or 40% of consumption in 2000. Electrical and electronics, a major end-use in 2000, accounted for about 32,000 kilograms or 27% of overall PGM consumption. Jewelry, a major end use of platinum worldwide (especially in Japan), accounted for only about 8,000 kilograms (7%) of U.S. consumption in 2000. Another 44,000 kilograms (37%) of PGM were used in other domestic applications, including petroleum reforming catalysts, chemical process catalysts, dental and medical devices, and the glass industry.

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Ruthenium pastes are used in the manufacture of resistors, which are found in all electronic devices. In 2000, sales of products such as mobile phones, computers, and video games pushed the output of resistors up by more than 30%. Also, prices were influenced by reports of a ruthenium-based material that will eventually permit hard disk drives to store 100 gigabits of data per square inch of disk area. Current technology is limited to data densities of 20 to 40 gigabits per square inch.

According to Johnson Matthey plc, global automobile demand for rhodium was expected to increase by 1,700 kg to 17,500 kg in 2000, boosted by higher vehicle production, tighter emissions standards, and changes in the PGM mix in autocatalysts. Stage III European emissions legislation came into force in 2000, leading to an increase in average rhodium loadings. Although European Union stage IV regulations will not take effect until 2005, fiscal incentives encouraged some car manufacturers to fit automobiles with catalysts capable of meeting stricter limits much sooner. Japan also saw an increase in rhodium demand in response to new legislation. Japan's Low Emissions Vehicle regulations were imposed in October 2000, but many automakers had adopted catalysts capable of meeting the new limits ahead of this deadline. Loadings on Japanese export vehicles have also increased, in line with tightening emissions limits in Europe and the United States (Johnson Matthey plc, 2000).

Legislation and Government Programs

In June 2000, the U.S. Defense Logistics Agency (DLA) requested the U.S. Mint to return 6,219 kg of platinum loaned in 1997 for the Mint's American Eagle Bullion program. DLA requested the return of the metal so that it could complete its fiscal year 2000 sales and prepare for its fiscal year 2001 sales. Under its Annual Materials Plan for fiscal year 2000, DLA was authorized to sell 3,888 kg of platinum. DLA was also authorized to sell the same amount of platinum in fiscal year 2001 and needs the material from the Mint to complete its sales. The terms of the 1997 agreement between the Mint and DLA required that a like amount of platinum of similar quality be returned before the agreement expires in 2003. If the occasion should arise, as it did in June 2000, the mint was required to return the metal upon 30 days notice. DLA requested that 50% of the material be returned by March 31, 2000, and the balance returned by June 30, 2000, so that the agency would be positioned to offer the material for sale by October 1, 2000 (Platt's Metals Week, 2000a). On August 25, DLA announced that the Annual Materials Plan for palladium would be increased by 3,110 kg for fiscal year 2000 and the Defense National Stockpile Center reactivated its PGM sales program on August 28, 2000.

Production

World mine production of PGM decreased by about 3%, to 365,000 kg compared with 376,000 kg in 1999. In South Africa, the world's leading producer, PGM output decreased by about 11% to 201,800 kg. Production in Russia, the world's second largest producer, was estimated to have increased by 11% to 128,100 kg.

The Stillwater Mining Co. operates the Stillwater Mine in Nye, MT. The company is the only primary palladium-platinum producer in the United States. In 2000, the Stillwater Mine reported production of 13,400 kg of palladium and platinum, over 5% higher than production in 1999. Of the 13,400 kg produced, palladium accounted for 10,300 kg, and platinum accounted for 3,110 kg. Mine production is defined by Stillwater as the quantity of PGM contained in a concentrate at the time it was shipped to the smelter. The company milled 617,000 metric tons of ore in 2000, 2% less than in 1999. The mill head grade was 21.5 grams per metric ton (g/t) of combined palladium and platinum in 2000, compared with 20.5 g/t in 1999. East Boulder, Stillwater's new mine, changed its focus in 2000 from surface construction to underground development. The concentrator and other surface facilities were essentially complete. During 2001, Stillwater expects to process a limited amount of ore through the concentrator from ore removed during the course of mine development work. Stillwater expected that the East Boulder Mine would move to commercial production during 2002 (Stillwater Mining Co., 2001, p. 9-14).

Stillwater operates a smelter and base metal refinery at its metallurgical complex in Columbus, MT. Expansions at the smelter were completed in 1999 and the smelter completed its first full year of operation in 2000. The smelter recorded a 12% increase in PGM produced, while reducing sulfur dioxide emissions by 67% compared with that of 1999. In the fourth quarter of 2000, the smelter shipped 445 kg of platinum and palladium contained in a matte, a quarterly record for the company.

Stillwater's automobile catalyst recycling effort also continued in 2000. The smelter processed more than 2metric tons per day of spent autocatalyst in 2000, containing 929 kg of palladium and platinum, more than double the 390 kg processed in 1999. Spent autocatalysts typically contain three parts platinum to one part palladium, reflecting the metals use in older clean-air technology. This ratio will shift in time as the palladium-dominated catalysts used in 1999-2000 begin to be recycled.

In 2000, Stillwater completed construction of a copper-dissolve-pressure-leach and selenium/tellurium removal circuits at its base-metal refinery. The function of the copper-dissolve-pressure-leach is to increase PGM production and provide ideal copper solution feed to the selenium/tellurium removal circuit. The selenium/tellurium circuit, as the name implies, removes selenium and tellurium from the copper solution that feeds a copper electrowinning circuit. The refining process removes small amounts of copper, gold, nickel, and rhodium to produce a final palladium-platinum product. A nickel sulfate crystallizer was also in the final stages of construction. Stillwater expected this circuit to be completed in the first half of 2001. The crystallizer will allow the company to ship its nickel sulfate byproduct as a solid rather than a liquid. The nickel sulfate is shipped to Canada for further refining. The final palladium-platinum product is shipped to California and New Jersey where it is converted into palladium and platinum sponge. The sponge is then sold, primarily for use in catalytic converters (Stillwater Mining Co., 2001, p. 18-21).

Proven and probable reserves of the company are contained in the J-M Reef in southern Montana. The average ratio of palladium to platinum contained in the reef is 3.3 to 1. At yearend 2000, proven and probable reserves, including the Stillwater and East Boulder Mines, contained 786,000 kg of palladium and platinum in 35.6 million metric tons (Mt) of ore grading 22.1 g/t of combined palladium and platinum.

Secondary production of PGM from spent autocatalysts and other PGM-bearing waste materials yielded increased amounts

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of metal in 2000 when compared with that of 1999. Large amounts of platinum contained in catalytic converters from end-of-life vehicles helped push global recovered platinum from this source to 14,600 kg in 2000 versus 13,100 in 1999. U.S. secondary production of platinum was estimated at about 12,000 kg. Increasingly stringent regulations designed to reduce emissions prompted higher loadings of palladium in autocatalysts. Increased demand and short supplies prompted sharply higher prices and an attendant increase in the secondary recovery of palladium. About 7,200 kg were recovered globally in 2000, up from slightly more than 6,000 kg in 1999. Johnson Matthey reported that global recovery of rhodium from spent autocatalysts reached 2,430 kg in 2000, up 20% from 2,020 kg in 1999. The United States accounted for most of the increase, although significant increases were reported for Europe and Japan (Johnson Matthey plc, 2001, p. 49-52).

Consumption

In 2000, total world demand for platinum was up only slightly from 1999 and was estimated by Johnson Matthey at about 174,000 kg (Johnson Matthey plc, 2001, p. 48). U.S. apparent consumption of platinum was about 50,000 kg, or 28% of world demand. U.S. industry consumed an additional 12,000 kg of platinum that had been recovered from spent autocatalysts. World demand for palladium was down 3% from a near record 292,000 kg in 1999 to 277,000 kg in 2000. U.S. apparent consumption of palladium was estimated at 104,000 kg or 38% of world demand.

Platinum.—In 1999, demand for platinum by U.S. automakers declined for the third consecutive year, despite increased auto sales in the United States and Canada. Platinum demand declined because PGM loadings on catalytic converters had shifted toward palladium-rich catalysts. In 2000, demand for platinum in autocatalysts accounted for about 33% of total demand, growing by 14% to 57,200 kg. This was the first increase in 4 years for this sector of platinum demand. The increase was driven by automakers' efforts to reduce the palladium content in catalyst formulations and the move in Europe to diesel engines as new emissions standards are introduced. Platinum loaded autocatalysts are more efficient than palladium loaded catalysts on diesel engines. In the United States, there was a return to the use of platinum catalysts for gasoline engines. Automobile manufactures were under increasing pressure to reduce the amount of emissions from vehicles. In order to meet the new standards and keep prices down, automakers needed to reduce their dependence on the more expensive palladium.

Global demand for platinum in jewelry declined for the first time in 16 years, down by 1% to 88,300 kg. Increases of 15% in the United States, 16% in China, and a steady growth in Europe were more than offset by a 20% decline to 33,000 kg in Japan (Mining Journal, 2001a).

Palladium.—High prices had a negative impact on demand for palladium which declined by 9.7% to 277,000 kg. Higher prices had the greatest impact on the automobile sector where demand fell 12% to 161,000 kg. The electronics industry was also hit by high palladium prices, however, producers of multilayer ceramic capacitors (MLCC) were successful in replacing palladium with lower priced nickel and silver. Consequently, the proportion of MLCCs using palladium decreased from 62% in 1999 to 46% in 2000. Nevertheless, MLCC output rose by 47% in 2000, offsetting palladium's loss of market share. As a result, demand from the electronics sector increased by 5% to 64,400 kg. Although overall demand was down in 2000, it is important to note that supply was down as well, from 252,000 kg to 246,000 kg, mainly due to lower Russian sales. Global demand exceeded global supply by 14,900 kg (CRU Quarterly Market Service Report, 2001).

Rhodium.—The rhodium market was characterized by strong consumer demand and tight supplies. Demand for rhodium increased in all regions, driven by the need to meet tougher emission standards in Europe, Japan, and the United States. Rhodium was added to some palladium-only catalyst systems to meet more rigorous emissions control standards, as automakers attempted to minimize their dependence on palladium. New legislation coming into effect over the next few years is directed at hydrocarbon emissions for which palladium is particularly effective as a catalyst. The addition of rhodium to palladium-only catalyst, however, helps lower the overall PGM loading. Autocatalysts accounted for more than 90% of demand. Rhodium's other principal applications were in the manufacture of specialty chemicals and the glass industry. Sales to the glass industry, 1,300 kg, were strong in 2000, driven by the construction of new plants to manufacture the high-quality thin glass used in liquid crystal displays. Johnson Matthey estimates world demand for rhodium in 2000 at about 25,000 kg, 98% of which was used in autocatalysts. The amount of rhodium recovered from scrapped catalytic converters increased 20% to 2,400 kg, more than one-half of which were removed from cars in the United States, where rhodium levels in autocatalysts increased significantly in the early 1990s.

Iridium and Ruthenium.—Demand for ruthenium remained strong in 2000 as it was used in a new process that manufactured feed stock for the production of solvents and synthetic fibers. Consumption of ruthenium in catalysts used in the Kellogg advanced ammonia process was also strong in 2000. The process required less stringent operating conditions than traditional base metal catalysts, and thus substantially reduced energy costs.

Continuing growth in the electronics industry was the driving force in increased demand for both iridium and ruthenium. The largest consumption of ruthenium was in the production thick film paste used in the manufacture of resistors. Increased production of resistors, for use in consumer electronics, was somewhat offset by the miniaturization of electronic components.

Reduced sales of iridium automobile and chemical-process catalysts were more than offset by strong demand for crucibles for growing synthetic crystals, especially single crystal sapphires. During 2000, there was significant growth in the demand for mobile phones with production of these devices growing by almost 50%. This generated a comparable demand for lithium-based crystals, which are used in surface acoustic wave filters to prevent signal interference between individual phones. These crystals are grown in iridium crucibles. There was a significant increase in production capacity of these crystals in 2000 which led to an almost threefold increase in iridium consumption in this application.

The electrochemical industry accounts for significant portions of total demand for iridium and ruthenium. Electrodes coated with either iridium or ruthenium or a mixture of iridium and ruthenium are used in a number of electrochemical processes. The most important of these is the chlor-alkali process which is

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used to produce chlorine and caustic soda from brine.

Prices

Russian shipments of PGM were delayed again in 2000, exerting upward pressure on PGM prices. Concern about supplies continued to run high as late as May when Russia resumed sales on a spot basis. Russia had offered spot palladium in the first few weeks of 2000 and resumed offering spot platinum in May. Even though Russia returned to the spot market, it remained silent about whether it would supply PGM under long-term contracts. Russia supplies more than 60% of the world's palladium and about 25% of the world's platinum.

Palladium.—The palladium price set an alltime record in 2000, ending the year at an average of $691.84 per ounce. After starting the year at $437, the price began to rise later in January, stimulated by strong demand and a shortage of the metal from Russia. Price increases steepened in February, reaching $815 on February 22. This gain was mostly due to panic buying on the Tokyo Commodities Exchange (TOCOM). On February 23, TOCOM suspended trading of palladium futures and froze prices to allow the orderly liquidation of contracts. On February 24, the palladium price fell abruptly below $700. The price decline was short lived, owing to continued shortages of physical metal, which supported a palladium price above $700 for much of March. Prices began to sink again following rumors of imminent shipments from Russia, falling to around $570 on March 31. Prices began to climb in April, encouraged by strong physical demand, an increase in lease rates, and the cancellation of TOCOM restrictions on palladium contracts. The rally continued, culminating on August 2, when the price of palladium reached a new high of $865. The rally ended quickly as prices fell to $720 on August 28. Palladium prices made even more dramatic gains in December when it was reported that RAO Norilsk Nickel had exhausted its palladium export quota for 2000 and that the Russian Government had no plans to sell more metal. The price climbed rapidly above $900, finally reaching a record high of $985 on December 27.

Platinum.—Platinum prices advanced strongly in 2000, rising from a low of $416 per ounce on January 6 and closing the year at an average $549.31 per ounce. The low was in response to reports that the President of Russia had signed a revision to a clause in the 1999 budget bill that provided the legal framework for the resumption of platinum exports. Platinum exports had been delayed since April 1999. Prices began to rise during the middle of January as it became clear that, despite the revision, shipments from Russia would not resume immediately. Prices continued to climb through February, reaching an 11-year high of $573 on February 17. Prices fell to around $460 in the first week of March and experienced wide swings in April before settling between $470 and $570 through July. Prices increased sharply again in August, driven by lack of shipments from Russia and lifted by palladium's record price. On August 2, the platinum price reached $615, its highest level since 1988. The rally ended abruptly as reports circulated that Norilsk Nickel expected to ship metal to Japan in September or October. Prices made gains in September, rising above $600 on several occasions, but began to weaken again in mid-September, falling to a low of $582 on September 26. Prices began to rise again in early November reaching $625 on the 28th. Again the increase was driven by a shortage of physical metal supplies from Russia. The increases continued into December with prices reaching $625 on the 13th and again on the 28th, its highest price since August 1987. Prices continued to trade above $600 for the remainder of the year.

Iridium, Rhodium, and Ruthenium.—Strong consumer demand and short physical supplies pushed the price of rhodium to an 8-year high of $2,600 per ounce in August 2000. Increased sales from Russia caused prices to weaken to $1,625 in October, before recovering to $2,025 at yearend. Industrial buying propelled the price of ruthenium to a high of $170 per ounce in August, but iridium was unchanged at $415 per ounce throughout the year (Johnson Matthey plc, 2001, p. 45-46).

Trade

In 2000, U.S. net import reliance as a percentage of apparent consumption was estimated at 89% for palladium and 83% for platinum. South Africa accounted for 64% of refined platinum and 12% of refined palladium imports; Russia accounted for 51% of refined palladium and 3% of refined platinum imports. Palladium imports decreased 4% to 182,000 kg from 189,000 kg in 1999; platinum imports were down 25% in 2000 to 94,000 kg from 125,000 kg in 1999. U.S. exports were 58,600 kg of palladium, 25,000 kg of platinum, and small amounts of other PGM.

World Review

Russia.—Russian sales of platinum and rhodium increased in 2000 following the resolution of policy issues that had prevented exports for much of 1999. The policy restricted PGM exports to authorized "State Organs." Russia's sole PGM exporter, Almazjuvelirexport, did not fit this description and neither did any other Russian organization (Platt's Metals Week, 2000c). Palladium sales were less affected in 1999 because Norilsk Nickel, Russia's primary PGM producer, had been given a 10-year quota and export license for its product. Although Russia does not publish its PGM statistics, it is generally accepted by the industry that Norilsk Nickel has an annual output of 20 to 22 metric tons per year (t/yr). Norilsk has an annual quota, authorized by the Government, to export its platinum (also palladium and rhodium), and it receives the world market value from buyers. This policy does not apply to other Russian producers. Koryakgeoldobycha (KGD), Russia's leading alluvial producer, and other alluvial producers concentrated in the Russian Far East account for about 10 t/yr of PGM output (Platt's Metals Week, 2000b). Gokhran, the State metal stocking agency, has a pricing policy that offered alluvial producers 20% to 30% less than the international market value for their metal. This discrepancy led to a dispute between the alluvial platinum producers and Gokhran, as the producers refused to sell at Gokhran's price. KGD began stockpiling its platinum rather than sell to Gokhran. KGD reportedly has a large stockpile unsold from 2000 and plans to hold up to 2,200 kg of platinum while it waits for a change in State pricing policy. Gokhran has not announced any changes in its pricing policy. Meanwhile, KGD planned to increase its platinum output to 4,400 kg in 2001 from 3,300 kg in 2000. The company is also asked the Government for permission to export its metal without having to go through Gokhran (Platt's Metals Week, 2000b).

South Africa.—Along with byproduct cobalt, copper, gold, nickel, and silver, PGM occurs in South Africa in three separate

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layered reefs associated with mafic rocks in the Rustenburg Layered Suite of the Bushveld Complex in the Transvaal. The reefs are the Merensky Reef, the UG2 Chromite Layer, and the Platreef. The PGM occurs as alloyed native metals, as platinoid minerals (such as sperrylite and braggite) and in copper, nickel, cobalt, and iron sulfide minerals (such as chalcopyrite, pentlandite, and pyrrhotite).

Rustenburg Platinum Mines Ltd. (RPM), a subsidiary of Anglo American Platinum Corp., Ltd., was the largest single South African PGM producer and operated three geographically separate sections, all on the western limb of the Bushveld Complex. The other mines on the western limb are the two adjoining Impala Platinum Ltd. (Implats) Mines, Bafokeng North Mine and Wildebeestfontein South; the two Lonmin Platinum Division mines, Eastern Platinum Ltd. and Western Platinum Ltd.; and Northam Platinum Ltd. (Department of Minerals and Energy, 1997, p. 34-36).

In 2000, South Africa produced about 201,800 kg of PGM, about 11% less than the 224,600 kg produced in 1999. Production fell because of a combination of heavy rainfall and strike actions at Anglo American Platinum, the world's leading producer of PGM. Production of platinum at Anglo Platinum fell by 4,700 kg to 58,200 kg. Implats' production was also impacted by the heavy rains. Although mining itself was unaffected by the poor weather, the collapse of a conveyor belt disrupted mineral processing and was the main reason for a 2,330 kg drop in output to 31,100 kg. Lonmin, plc, which is further east, and was less affected by the inclement weather, increased production by 4% to 20,200 kg. Northam Platinum Ltd. output was virtually unchanged at 5,510 kg while Kroondal, which completed its first year of full production, produced 2,000 kg of platinum (Mining Journal, 2001b).

The positive outlook for PGM markets resulted in a number of expansion plans by South African producers. Anglo American Platinum announced that it would invest R12 billion to expand output from 62,200 kg to 109,000 kilograms per year (kg/yr) of refined platinum by 2006. Of the announced expansions, those at the Amandelbult Mine and Lebowa Mine, with a combined output of 3,330 kg, were completed in 2000. A new mine, costing R1.3 billion in Maandagshoek, with a production capacity of about 5,000 kg/yr of platinum, was scheduled to come into operation by 2004 (Metal Bulletin, 2000a).

Implats reopened the Crocodile River Mine and opencast mining began in December 2000. At full production, the mine's platinum output reportedly will be 1,600 kg/yr. In December 2000, the company announced its purchase of 100% of Platexco, Inc., a Canadian listed company that owns the Winnaarshoek property on the eastern limb of the Bushveld Complex. Mining is expected to begin in 2002, and full production of 6,220 kg/yr of platinum is planned for the end of 2003 (Mining Journal, 2001).

The Kroondal platinum mine in South Africa planned to triple production of PGM to 15,900 kg/yr in a joint venture with Amplats. Kroondal started commercial production in September 1999, and reached full production within 3 months. Under the proposed joint venture, RPM will contribute portions of its UG2-reef mineral rights, while RPM will contribute the existing mine and plant as well as its own mineral rights. The mineral rights contribution from RPM will lift the projects *in situ* resources to nearly 60 Mt of UG2 ore, and is designed to ensure a mine life of 13 years. The partners intend to expand the existing plant from its current design capacity of 5,290 kg of PGM (3,110 kg/yr of platinum 1,680 kg of palladium, and 498 kg of rhodium) to 7,930 kg/yr of PGM per year, including 4,670 kg of platinum. A new concentrator, which will be built next to the mine's eastern decline, will have a similar capacity, boosting Kroondal's annual output by 1,590 kg (9,330 kg platinum) from a total feed of 5.4 Mt of ore (Mining Journal, 2000).

Zimbabwe.—In 1999, Zimbabwe produced about 7,200 kg of PGM but its major primary producer, Hartley Platinum, was closed in June 2000. Following the closure of Hartley, Zimbabwe's only primary production came from the small Mimosa Mine, with an output of about 600 kg/yr. Mining investments in Zimbabwe have often been discouraged by political and economic instability. In 2000, there was the prospect of a new framework for investing in platinum mining, with the Government expected to relax foreign exchange restrictions and reduce the tax rate on platinum operations. An improved climate for investment will likely lead to funding for the development of the Ngezi opencast mine. Zimbabwe Platinum Mines Ltd. (Zimplats), which owns the mine, reported that it had carried out a 3-month trial mining program at Ngezi and full-scale mining would begin as soon as new mining legislation is passed. The Ngezi platinum mine is expected to produce a minimum 2 million metric tons per year (Mt/yr) of unrefined ore. A 2 Mt/yr mining rate is considered a minimum and, if the project proceeds, the tonnage is expected to increase. The mine processing plant would consist of a conventional crusher, mill, concentrator, and dryer. Dried metal in sulfide concentrate would be the mine end-product for sale or toll refining of the contained palladium, platinum, copper, nickel, and gold. Zimplats is also interested in restarting activities at the closed Hartley platinum mine and an agreement has been reached by Zimplats and the Zimbabwe Government on the takeover. Zimplats owned a 33.3% share in Australia-based Broken Hill Proprietary Co. Ltd. before the company closed Hartley (Metal Bulletin, 2000b).

Current Research and Technology

Palladium-Silver Resistors for High-Power Applications.—With the advent of ruthenium-based resistors, the use of palladium-silver resistors on thick film circuits was all but discontinued until the 1990s when demand in new niche applications led to their resurgence. The relatively high power-handling of these metallic resistors enabled them to be used as secondary lightening surge protection devices for communications equipment. For such applications, low-value compositions, about 0.1 to 1 ohm-milimeter^2/centimeter (Ω/□), are printed in a serpentine configuration, typically about 1.27-centimeter (cm) x 2.54-cm area, to fabricate 10-to 300-ohm components. More recently, the resistance range of interest to circuit designers has shifted down to as low as 5.6 ohms. Although it is possible to design 5.6-ohm resistors using the existing 0.1 Ω/□-inks, the resulting area would be quite large, resulting in bulky circuits. This points to a need for low resistivity inks with more robust power handling capability. A new series of palladium-silver inks with resistivity as low as 0.015 Ω/□ have been developed. The palladium-silver resistors can extend the reach of thick film technology into high power applications that were formerly reserved for bulky wire-wound resistors (Printed Circuit Design, 2000).

Advances in PEM Fuel Cells.—Under terms of an agreement

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between Johnson Matthey and James Cropper plc, Technical Fibre Products, the advanced composites subsidiary of James Cropper, will provide key components in Johnson Matthey's new Membrane Electrode Assembly (MEA) products for fuel cells. The agreement centers upon the development of carbon composite substrates to be used to support the [platinum] catalysts and other MEA components that form the heart of polymer electrolyte membrane (PEM) fuel cells. There now seems little doubt that fuel cells will emerge as a major propulsion system for cars and trucks within the next 5 to 10 years and will generate an additional demand for about 500,000 kg of platinum. Offering an attractive driving range and quick refueling, fuel cells may displace various high-energy battery options that are now being investigated to meet zero emission requirements on vehicles in the United States (Platt's Metals Week, 2000b).

Currently, fuel cell power units cost about 10 times that of conventional gasoline engines and use hydrogen (liquid or gas) as the primary fuel. Most researchers in the field, however, have begun investigating alternatives to pure hydrogen as the primary fuel because of difficulties associated with its storage and distribution and are considering the use of methanol. Methanol is low in carbon and rich in hydrogen. Fuel cell power systems fueled by methanol would require a reformer subsystem to convert methanol to the hydrogen required. One disadvantage of methanol is that, unlike the use of pure hydrogen, water would not be the only exhaust pipe emission; carbon monoxide, carbon dioxide, and nitrogen oxides would also be emitted (Metal Bulletin Monthly, 2000). In a related project, researchers at NASA's Jet Propulsion Laboratory, Pasadena, CA, have developed an improved method of fabricating PEM-electrode structures for methanol fuel cells. The procedure involves the use of improved sprayers to deposit inks containing [platinum] catalytic metals onto proton exchange membranes of perflurosulfonic acid polymers. The inks usually contain the catalytic metal (platinum for the cathode and a mixture of platinum and ruthenium for the anode), a proton conducting ionomer solution, water, and isopropanol, with perhaps a small amount of a polytetrafluoroethylene-based additive. In experiments, the performances of fuel cells containing electrode structures made by the new method were found to be comparable to fuel cells made by older methods. The amount of catalyst used in the new method, however, ranged from 1 to 2 milligrams per square centimeter (mg/cm^2), whereas the amounts used in the older methods were typically about 4 mg/cm^2. The new method is suitable for mass production and may be a significant step toward commercialization and reducing the cost of fuel cells (NASA Tech Briefs, 2000).

New Fuel Cell May Eliminates Need for Platinum.—The most commonly used fuel cells contain platinum catalysts to convert conventional fuels into hydrogen fuel. Researchers in Japan have designed a solid-oxide fuel cell (SOFC) that advances the prospect of using fuel cells for onboard power generation in transportation applications that require the use of conventional fuels. The system consists of only one gas chamber in which both the anode and cathode are exposed to the same mixture of fuel and air. This design eliminates the need for a reformer, which uses a platinum catalyst, to convert hydrogen rich hydrocarbons to hydrogen. SOFCs have several advantages over more commonly used PEM fuel cells. For example, SOFCs do not require conversion of hydrocarbons to hydrogen, and SOFCs have a lower fabrication cost because they do not require the use of platinum catalysts. In addition, the anode in SOFCs is not poisoned by carbon monoxide, a major problem with PEM fuel cells that decrease their performance when conventional fuels are used directly. The new SOFC design also is compact and takes up less space than PEM cells. That advantage, combined with no need for an onboard reformer, makes the SOFC system attractive for transportation applications (Environmental Science & Technology, 2000, p. 419A).

Outlook

Despite the forecast of reduced world economic activity, demand for platinum is expected to continue to increase. Future demand is expected to be influenced by the automobile industry as sales of diesel powered vehicles increase in Europe and Japanese and U.S. automakers add platinum to autocatalyst on gasoline engines in an effort to reduce their dependence on palladium. Jewelry manufacturing, which accounts for a major portion of platinum demand, is expected to weaken in 2001. Weak economies in Japan coupled with high prices over the past year caused demand at the lower end of the jewelry market to shift to cheaper materials, such as white gold. Demand for platinum jewelry in China was on the rise, increasing 22% to 34,200 kg in 2000. China, second largest jewelry consuming market after Japan, imports most of its demand for platinum and may strengthen controls over imports to discourage illegal trading (China Metal Market, 2001). Demand for platinum in industrial applications is expected to rise but at a slower rate than in the previous 2 to 3 years owing to a decline in world economic conditions.

Rising palladium prices in 1999-2000 led to increased substitution of base metals for palladium in the electronics and dental industries, and automakers made clear their intentions to reduce dependence on the metal. Despite substitutions and further loss of market share in multilayer ceramic capacitors, palladium demand actually increased in this sector. The electronic device market appears to be in a downturn and electronic component manufacturers are beginning to cut back production. Thus, demand for palladium from this sector will likely fall in the next 1 to 2 years and palladium prices will drop back to historical levels.

References Cited

China Metal Market, 2001, China platinum demand reached 1.1 million oz in 2000: China Metal Market, no. 17, May, p. 3.

CRU Quarterly Market Service Report, 2001, Palladium: CRU Quarterly Market Service Report, 2d quarter, p. 4.

Department of Minerals and Energy, 1997, Platinum-group metals: Braamfontein, South Africa, Department of Minerals and Energy, November, p. 34-36.

———1999, Platinum-group metals: Braamfontein, South Africa, Department of Minerals and Energy, November, p. 39-44.

Environmental Science & Technology, 2000, Fuel cell breakthrough: Environmental Science & Technology, v. 34, no. 19, October 1, p. 401A-440A.

Johnson Matthey plc, 2000, Platinum 2000—Interim review: Johnson Matthey plc, November, p. 2-18.

———2001, Platinum 2001: Johnson Matthey plc, May, p. 47-52.

Metal Bulletin, 2000a, Anglo invests in platinum expansion: Metal Bulletin, no. 8476, May 18, p. 9.

———2000b, Ngezi feasibility study is completed: Metal Bulletin, no. 8472, May 4, p. 7.

Metal Bulletin Monthly, 2000, Fuel cells hit the road: Metal Bulletin Monthly, no. 342, p. 62.

Digitized by Google

Mining Journal, 2000, Kroondal to triple output: Mining Journal, v. 335, no. 8597, August 25, p. 148.
———2001a, Palladium 2001: Mining Journal, v. 336, no. 8634, May 18, p. 386.
———2001b, Platinum metals shine: Mining Journal, v. 36, no. 8634, May 18, p. 378.
———2001c, Precious metals focus: Mining Journal, v. 36, no. 8634, May 18, p. 379.
NASA Tech Briefs, 2000, Improved fabrication of electrodes for methanol fuel cells: NASA Tech Briefs, v. 23, no. 4, April, p. 9-11.
Platt's Metals Week, 1999, Russian platinum exports unlikely this year: Platt's Metals Week, v. 70, no. 44, November 1, p. 1.
———2000a, DLA requests return of loaned platinum from U.S. Mint: Platt's Metals Week, v. 71, no. 6, February 7, p. 14.
———2000b, Palladium mine expansion on track: Platt's Metals Week, v. 71, no. 38, September 18, p. 15.
———2000c, Russian platinum producer plans to stockpile: Platt's Metals Week, v. 71, no. 44, October 30, p. 13.
Printed Circuit Design, 2000, Thick film resistors: Printed Circuit Design, v. 17, no. 5, May, p. 46-50.
Stillwater Mining Co., 2001, 2000 annual report: Columbus, MT, Stillwater Mining Co., March 31, 62 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Precious Metals. Mineral Industry Surveys, monthly.
Platinum-Group Metals. Ch. in Mineral Commodity Summaries, annual.
Platinum-Group Metals. Ch. in Minerals Yearbook, annual.
Platinum-Group Metals. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Platinum-Group Metals. International Strategic Minerals Inventory Summary Report, Circular 930-E, 1986.

TABLE 1
SALIENT PLATINUM-GROUP METALS STATISTICS 1/

(Kilograms metal content, unless otherwise specified)

		1996	1997	1998	1999	2000
United States:						
Mine production:						
Palladium 2/		6,100	8,430	10,600	9,800	10,300
Value	thousands	$25,600	$49,900	$98,500	$114,000	$228,000
Platinum 2/		1,840	2,610	3,240	2,920	3,110
Value	thousands	$23,500	$33,300	$39,000	$35,600	$69,200
Refinery production:						
Palladium		NA	NA	NA	14,400	13,500
Value	thousands	NA	NA	NA	$168,000	$224,000
Platinum		NA	NA	NA	14,000	17,500
Value	thousands	NA	NA	NA	$172,000	$308,000
Imports for consumption, refined:						
Iridium		1,810	1,860	1,950	2,250	2,700
Osmium		NA	54	71	23	133
Palladium		146,000	148,000	176,000	189,000	181,000
Platinum, includes waste, scrap, and coins		75,800	77,300	96,700	125,000 r/	94,000
Rhodium		9,650	14,400	13,500	10,300 r/	18,200
Ruthenium		15,600	11,500	8,880	11,400	20,900
Exports, refined:						
Iridium, osmium, and ruthenium (gross weight)		122	574	905	851	1,480
Palladium		26,700	43,800	36,700	43,800 r/	58,600
Platinum		12,700	23,000	14,300	19,400	25,000
Rhodium		187	282	811	114	797
Stocks, National Defense Stockpile, December 31:						
Iridium		920	920	920	784	784
Palladium		39,300	39,300	38,800	28,200	19,000
Platinum		14,100	14,100	13,700	7,060	5,190
Price, average per troy ounce:						
Iridium 3/		$74.00	$205.42	$441.85	$411.40	$415.00
Palladium 4/		$130.39	$184.14	$289.76	$363.20	$691.84
Platinum 4/		$398.07	$396.59	$374.61	$378.94	$549.31
Rhodium 4/		$308.30	$298.00	$619.83	$904.35	$1,990.00
Ruthenium 3/		$47.56	$40.51	$47.95	$40.70	$129.76
Employment		500	550	620	954 r/	1,290
World, mine production		324,000	333,000	348,000 r/	376,000 r/	365,000 e/

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to no more than three significant digits; except for prices.
2/ Source: Stillwater Mining Co., 2000 10-K report, p. 80.
3/ Price data are annual averages of daily Engelhard unfabricated quotations published in Platts Metals Week.
4/ Price data are annual Engelhard unfabricated quotations published in Platts Metals Week.

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TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Platinum grain and nuggets		Platinum sponge		Other unwrought platinum		Platinum, other		Platinum waste and scrap		Platinum coins	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
1999	6,100	$76,300	74,300 r/	$738,000 r/	7,820	$96,000	16,500	$187,000	19,700	$47,100 r/	171 r/	$2,260 r/
2000:												
Australia	--	--	--	--	--	--	144	2,340	59	1,110	2	106
Belgium	129	1,920	4,910	83,500	122	1,560	--	--	--	--	--	--
Brazil	--	--	--	--	--	--	301	4,080	418	2,830	--	--
Canada	20	336	31	609	33	601	878	15,100	9,350	12,800	20	330
Chile	--	--	--	--	--	--	351	4,740	--	--	--	--
China	--	--	--	--	5	69	--	--	4	83	(2/)	5
Colombia	3	42	--	--	221	3,620	--	--	(2/)	33	--	--
Estonia	--	--	--	--	32	548	--	--	--	--	--	--
France	--	--	12	188	--	--	2	19	135	4,150	--	--
Germany	669	10,200	4,370	77,200	378	6,530	2,430	32,300	904	13,400	2	36
Honduras	--	--	--	--	--	--	--	--	--	--	--	--
Hong Kong	2	35	--	--	--	--	123	1,930	327	12,800	--	--
India	--	--	--	--	--	--	3	29	--	--	--	--
Indonesia	--	--	--	--	2	31	--	--	102	5,230	--	--
Ireland	--	--	--	--	39	742	2	24	--	--	--	--
Israel	--	--	(2/)	3	377	8,690	--	--	18	535	--	--
Italy	19	300	439	6,870	18	345	1	21	80	1,950	--	--
Japan	154	2,550	175	3,030	18	200	593	10,600	3	1,060	--	--
Korea, Republic of	19	699	--	--	--	--	1	4	91	4,720	--	--
Malaysia	--	--	--	--	--	--	13	157	7	168	--	--
Mexico	34	490	3	50	--	--	2	25	171	5,190	--	--
Netherlands	--	--	--	--	--	--	58	423	--	--	--	--
Norway	--	--	171	2,980	--	--	--	--	--	--	--	--
Peru	(2/)	6	--	--	--	--	--	--	5	116	--	--
Philippines	--	--	--	--	--	--	--	--	11	188	--	--
Poland	--	--	--	--	32	256	--	--	--	--	--	--
Russia	--	--	2,290	42,800	632	10,900	--	--	--	--	--	--
Saudi Arabia	--	--	4,630	7,960	--	--	--	--	1	25	--	--
Singapore	--	--	--	--	--	--	20	260	(2/)	43	--	--
South Africa	1,260	21,800	43,200	706,000	907	17,100	106	1,840	6	2,750	--	--
Spain	--	--	--	--	--	--	328	3,590	--	--	--	--
Sweden	1	8	--	--	--	--	--	--	--	--	--	--
Switzerland	92	1,820	363	7,120	737	13,400	1,260	15,200	--	--	--	--
Taiwan	--	--	--	--	2	17	2	34	66	2,010	--	--
Thailand	--	--	1	10	6	109	--	--	--	--	--	--
United Kingdom	146	2,660	7,370	114,000	304	5,470	869	18,000	201	13,900	3	51
Other	3	31	--	--	2	45	--	--	93	947	1	38
Total	2,550	42,900	68,000	1,050,000	3,870	70,200	7,480	111,000	12,100	86,000	27	565

See footnotes at end of table.

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TABLE 2--Continued
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Unwrought palladium		Palladium, other		Iridium 3/		Unwrought osmium		Unwrought ruthenium		Rhodium 4/	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
1999	165,000	$1,810,000	24,100	$275,000	2,250 r/	$25,100	23	$272	11,400	$14,700	10,300 r/	$274,000 r/
2000:												
Australia	--	--	--	--	--	--	--	--	--	--	525	33,100
Belgium	11,400	236,000	88	2,690	--	--	--	--	--	--	1,160	69,400
Brazil	223	5,370	--	--	--	--	--	--	--	--	3	123
Canada	3,640	66,100	55	685	42	210	--	--	1	5	14	1,970
Chile	--	--	35	646	--	--	--	--	--	--	--	--
China	1,630	20,700	192	1,580	--	--	--	--	--	--	18	915
Colombia	--	--	--	--	--	--	--	--	--	--	--	--
Estonia	145	3,350	--	--	--	--	--	--	--	--	16	710
France	--	--	1	4	48	785	--	--	89	281	25	1,930
Germany	4,420	87,300	2,630	49,300	118	1,540	6	92	971	3,130	361	17,800
Honduras	98	302	--	--	--	--	--	--	--	--	--	--
Hong Kong	--	--	--	--	--	--	--	--	--	--	--	--
India	--	--	--	--	--	--	--	--	--	--	--	--
Indonesia	--	--	--	--	--	--	--	--	--	--	--	--
Ireland	--	--	16	306	--	--	--	--	12	11	--	--
Israel	6	12	--	--	--	--	--	--	--	--	--	--
Italy	855	14,500	691	11,400	3	50	--	--	(2/)	2	(2/)	25
Japan	7,190	69,100	312	1,890	3	46	--	--	1	4	52	3,190
Korea, Republic of	24	425	2	15	--	--	--	--	--	--	11	886
Malaysia	--	--	--	--	--	--	--	--	--	--	--	--
Mexico	16	76	--	--	--	--	--	--	--	--	2	24
Netherlands	--	--	2	22	--	--	--	--	36	124	--	--
Norway	2,410	44,900	--	--	--	--	--	--	--	--	--	--
Peru	--	--	--	--	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	--	--	--	--	--	--	--	--
Poland	--	--	--	--	--	--	--	--	--	--	--	--
Russia	73,600	1,600,000	18,900	238,000	--	--	--	--	995	4,990	9,110	347,000
Saudi Arabia	--	--	--	--	--	--	--	--	60	309	--	--
Singapore	1	27	2	47	--	--	--	--	--	--	--	--
South Africa	20,400	409,000	1,210	24,000	1,470	11,000	127	1,040	17,700	37,300	5,800	300,000
Spain	--	--	--	--	--	--	--	--	--	--	--	--
Sweden	331	5,890	--	--	--	--	--	--	--	--	--	--
Switzerland	8,200	205,000	3,370	26,500	4	30	--	--	--	--	6	197
Taiwan	--	--	(2/)	13	--	--	--	--	--	--	(2/)	3
Thailand	--	--	--	--	--	--	--	--	--	--	--	--
United Kingdom	19,100	342,000	340	6,500	1,020	13,700	--	--	1,110	3,500	1,080	73,800
Other	--	--	--	--	--	--	--	--	--	--	--	--
Total	154,000	3,110,000	27,900	364,000	2,700	27,400	133	1,130	20,900	49,600	18,200	851,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Unwrought and other forms of iridium.

4/ Unwrought and other forms of rhodium.

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TABLE 3
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium ruthenium		Rhodium	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
1999	43,800 r/	$271,000 r/	19,400	$200,000	7,660	$320,000	851	$11,200	114	$5,310
2000:										
Argentina	3	16	4	26	--	--	--	--	--	--
Australia	462	6,070	422	3,670	--	--	1	7	(2/)	38
Austria	--	--	21	80	--	--	1	3	--	--
Bahamas, The	--	--	--	--	(2/)	8	--	--	--	--
Belarus	55	310	--	--	--	--	--	--	--	--
Belgium	954	12,000	116	1,690	72	4,410	3	17	8	316
Bermuda	2	3	2	9	--	--	--	--	--	--
Bolivia	--	--	--	--	--	--	1	32	--	--
Brazil	68	446	490	6,390	--	--	(2/)	10	--	--
Canada	6,440	39,800	1,990	25,800	410	13,800	52	1,240	64	5,070
Cayman Islands	2	8	18	224	--	--	--	--	--	--
Chile	42	62	713	4,050	--	--	--	--	--	--
China	1,590	20,600	23	281	3	100	(2/)	6	10	245
Colombia	--	--	3	39	--	--	--	--	--	--
Costa Rica	--	--	4	53	--	--	--	--	--	--
Cyprus	4	20	--	--	--	--	(2/)	7	--	--
Denmark	65	316	21	118	--	--	17	104	--	--
Dominican Republic	15	23	3	31	--	--	--	--	--	--
El Salvador	3	10	--	--	--	--	--	--	--	--
Finland	7	58	29	172	--	--	--	--	--	--
France	393	3,760	438	5,470	(2/)	4	85	1,390	--	--
French Polynesia	2	5	--	--	--	--	--	--	--	--
Germany	4,680	53,300	2,290	29,200	3,110	61,400	72	645	51	3,110
Greece	14	32	5	9	--	--	--	--	--	--
Guatemala	1	3	--	--	--	--	--	--	(2/)	9
Haiti	3	12	--	--	--	--	--	--	--	--
Hong Kong	234	722	1,200	16,200	7	309	63	848	2	362
Hungary	(2/)	3	--	--	--	--	--	--	--	--
Iceland	6	20	4	10	--	--	--	--	--	--
India	2	4	25	259	--	--	1	12	1	101
Indonesia	--	--	--	--	--	--	--	--	(2/)	8
Ireland	703	12,800	380	5,770	--	--	56	1,060	26	1,760
Israel	6,300	9,340	4	37	(2/)	7	(2/)	7	--	--
Italy	270	2,170	169	899	49	2,040	8	58	(2/)	8
Japan	10,900	127,000	3,190	48,800	435	14,800	302	1,940	280	23,200
Korea, Republic of	6,590	59,600	253	4,200	91	1,180	--	--	164	7,590

See footnotes at end of table.

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TABLE 3--Continued
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium ruthenium		Rhodium	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
1999	43,800 r/	$271,000 r/	19,400	$200,000	7,660	$320,000	851	$11,200	114	$5,310
2000:										
Kuwait	4	33	10	70	--	--	--	--	--	--
Lebanon	--	--	--	--	--	--	--	--	(2/)	20
Luxembourg	2	3	--	--	--	--	--	--	--	--
Malaysia	36	143	102	602	--	--	--	--	--	--
Mexico	63	393	142	1,180	1	3,690	--	--	1	106
Netherlands	1,120	12,400	78	483	1	80	57	412	--	--
Netherlands Antilles	--	--	--	--	11	260	--	--	--	--
New Zealand	84	500	7	28	--	--	1	8	--	--
Norway	20	84	1	7	--	--	--	--	--	--
Peru	--	--	2	24	--	--	--	--	--	--
Philippines	40	109	18	164	--	--	--	--	--	--
Poland	1	9	(2/)	3	--	--	--	--	--	--
Romania	--	--	6	46	--	--	--	--	--	--
Saudi Arabia	3	15	15	144	9	242	--	--	(2/)	4
Singapore	97	353	43	428	--	--	--	--	--	--
Slovenia	123	418	--	--	--	--	--	--	--	--
South Africa	469	10,900	218	5,340	16	521	--	--	122	3,010
Spain	145	624	461	6,080	--	--	--	--	--	--
Sweden	103	1,790	70	459	24	1,000	6	57	--	--
Switzerland	1,370	28,800	3,250	45,600	6	155	4	22	(2/)	4
Taiwan	7,290	49,300	365	4,260	(2/)	6	(2/)	3	31	1,790
Thailand	37	357	58	345	--	--	--	--	(2/)	64
Turkey	9	49	--	--	(2/)	11	--	--	(2/)	29
United Arab Emirates	10	58	--	--	--	--	--	--	(2/)	57
United Kingdom	7,700	63,400	8,280	75,200	3,120	107,000	752	9,290	36	3,880
Uruguay	--	--	29	322	--	--	--	--	--	--
Venezuela	(2/)	3	--	--	--	--	--	--	(2/)	3
Total	58,600	518,000	25,000	294,000	7,360	211,000	1,480	17,200	797	50,800

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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TABLE 4
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country 3/	1996	1997	1998	1999	2000 e/
Platinum:					
Australia e/ 4/	100	100	100	100	100
Canada	5,155	4,813	5,640	5,442	5,450
Colombia	672	409	437	440 e/	440
Finland e/	62 r/	60	50 r/	50	50
Japan 5/	816	693	533	737 r/	782 6/
Russia e/	25,000	25,000	25,000	27,000	30,000
Serbia and Montenegro e/	10	10	10	5	5
South Africa	105,000 e/	115,861	116,483	130,745	114,434 6/
United States 7/	1,840	2,610	3,240	2,920	3,110 6/
Zimbabwe	100 e/	345	2,730	479 r/	150
Total	139,000	150,000	154,000	168,000 r/	155,000
Palladium:					
Australia e/ 4/	400	400	400	400	400
Canada	8,082	7,545	8,905	8,592	8,600
Finland e/	182 6/	180	150 r/	150	150
Japan 5/	2,182	1,899	4,151	5,354 r/	4,712 6/
Russia e/	80,000	80,000	80,000	85,000	94,000
Serbia and Montenegro e/	50	50	50	25	25
South Africa	52,600 e/	55,675	56,608	63,600 e/	55,888 6/
United States 7/	6,100	8,430	10,600	9,800	10,300 6/
Zimbabwe e/	120	245	1,855 6/	342 r/ 6/	70
Total	150,000	154,000	163,000	173,000 r/	174,000
Other platinum-group metals:					
Canada e/	697	651	742	716	720
Russia e/	3,500	3,500	3,500	3,700	4,100
South Africa	30,636	24,930	27,052	30,300 e/	31,522 6/
Zimbabwe	5 e/	27	189	20 r/ e/	10
Total	34,800	29,100	31,500	34,700 r/	36,400
Grand total	324,000	333,000	348,000 r/	376,000 r/	365,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 27, 2001. Platinum-group metal (PGM) production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

3/ In addition to the countries listed, China, Indonesia, and the Philippines are believed to produce PGM, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. A part of this output not specifically reported by country is, however presumably included in this table credited to Japan.

4/ PGM recovered from nickel ore that is processed domestically. PGM in exported nickel ore are extracted in the importing countries, such as Japan, and are believed to be included in the production figures for those countries.

5/ Production derived entirely from imported ores.

6/ Reported figure.

7/ A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.

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POTASH

By James P. Searls

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Potash denotes a variety of mined and manufactured salts, all containing the element potassium in water-soluble form. At the end of the 19th century, potash was made from hardwood trees and was a mixture of potassium carbonate and potassium hydroxide, both of which are caustic. Lye meant sodium hydroxide, and potash lye was potassium hydroxide, a higher grade product that made a better (softer, facial) grade of soap. Since approximately 1950, the term potash has been used to indicate potassium chloride (KCl, sylvite), potassium sulfate [K_2SO_4, or sulfate of potash (SOP), sometimes a manufactured product], and potassium-magnesium sulfate [$K_2SO_4 \cdot 2MgSO_4$ or langbeinite or sulfate of potash magnesia (SOPM or K-Mag)]. Muriate of potash (MOP) is an acceptable mix of potassium chloride (95% or higher) and sodium chloride that includes minor amounts of other nontoxic minerals of the mined ore for fertilizer use and is neither the crude ore sylvinite nor pure sylvite. This publication has historically included potassium nitrate (KNO_3 or saltpeter, a manufactured product) or mixed sodium-potassium nitrate ($NaNO_3 + KNO_3$ or Chilean saltpeter, a natural product) because it functions as a potassic fertilizer. Saltpeter and Chilean saltpeter are still noted in the import tables (tables 8, 9). Alunite, feldspar, and muscovite are potassium-bearing minerals that are quite insoluble in water and are considered to be neither potassic fertilizers nor ores for price-competitive potassic fertilizers.

Potash is used primarily as an agricultural fertilizer (plant nutrient) because it is a source of soluble potassium, one of the three primary plant nutrients (the others are fixed nitrogen and soluble phosphorus). Potash and phosphorus are mined products, and fixed nitrogen is produced from the atmosphere by using industrial processes. Modern agricultural practice uses large amounts of these primary nutrients plus such additional nutrients as boron, calcium, chlorine, copper, iron, magnesium, manganese, molybdenum, sulfur, and zinc to ensure plant health and proper maturation. The three major plant nutrients have no substitutes, but low-nutrient-content alternative sources of plant nutrients, such as animal manure and guano, bone meal, compost, glauconite, and "tankage" from slaughterhouses, can be used. In addition, KCl is important in industrialized economies where it is used in oil well drilling mud, aluminum recycling processes, a steel heat-treating process, metal electroplating, snow and ice melting, and water softening. Potassium chloride may be used in the chlor-alkali industry to produce potassium hydroxide. The alkali potassium hydroxide is the precursor of potassium carbonate and is used for industrial water treatment, for producing potassium phosphates, and in soap manufacture. The alkaline salt potassium carbonate is used in the glass for television and computer monitor tube production, alkaline batteries, food products, pharmaceutical preparations, photography, some fire extinguishers, animal feed supplements, and as a catalyst for synthetic rubber manufacture. Generally, these uses have accounted for no more than 10% of the annual consumption in the United States, but this percentage varies because industrial end uses tend to vary with the domestic economy, whereas fertilizer end uses tend to vary with disparate world weather patterns, world demand, relative currency values, and other countries' economic gyrations and their ability to pay for either fertilizers or food stuffs.

Legislation and Government Programs

The 1993, a class-action potash antitrust lawsuit was filed in

Potash in the 20th Century

At the beginning of the 20th century potash was used for glassmaking, soapmaking, bleach, and making saltpeter. It was a fertilizer to such very high value crops as tobacco and cotton. In 1870, a mineral source of water-soluble potassium ore named "carnallite" had been found near Stassfurt, Germany, from which the vaunted German chemical industry learned to separate potassium chloride (KCl). During the First World War, there were no imports from Germany. Potassium was needed for the solid oxidizer potassium permanganate in First World War gas masks and as potassium nitrate, an oxidizer in the munitions and signaling rockets. The price of potash rose to $600 per ton measured in 1916 dollars. Potassic salts were extracted from subsurface Searles Lake brines in California, some Nebraska lake brines, the dust of cement plants, iron refinery dust in Pennsylvania, molasses refinery waste in Maryland, old-fashioned tree ashes in Michigan and Wisconsin, and kelp (seaweed) off the coast of California. After the war, Congress allocated money to find reasonably priced potash in the United States. In 1925, an oil exploration team in New Mexico noted sylvinite in a well east of Carlsbad, NM. Potash production as KCl commenced in New Mexico in 1932. Three mines were operating in the New Mexico Known Potash Resource Area by the beginning of the Second World War. The New Mexico reserves were seen to be finite in the 1950s as more mines started up, and after searching likely sedimentary basins in the United States, potash mine owners moved up to a showing of sylvinite in Saskatchewan, Canada. With difficulty, a huge high-grade resource of sylvinite was changed to reserves through technology. The year of peak U.S. potash production was 1966, as Canadian potash started to enter the U.S. market.

At the end of the 20th century, Canada provided approximately 90% of the KCl consumed in the United States.

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many places and consolidated to the U.S. District Court for Minnesota in Minneapolis, MN; it was dismissed by summary judgment in January 1997, except for a California State Court lawsuit which allows indirect consumers to participate and is treated differently, and an Illinois State Court complaint of antitrust. An appeal to the U.S. Court of Appeals for the Eighth Circuit resulted in affirmation of dismissal for some of the defendants and a divided decision reversing the dismissal for some of the other defendants. These latter defendants reargued the case before the U.S. Court of Appeals for the Eighth Circuit in September 1999, and the court of appeals affirmed the dismissal of the complaint for all defendants by summary judgment on February 17, 2000. The plaintiffs appealed to the U.S. Supreme Court for review through a writ of certiori, which was denied without comment on October 2, 2000 (Potash Corp. of Saskatchewan, Inc., 2001a). According to the same Securities and Exchange Commission filing, the California State Court lawsuit was dismissed by the end of the year, as was the Illinois State Court complaint.

Production

Production of all types and grades of potash in the United States could not be accurately published in 2000 because of proprietary data constraints. Production increased moderately compared with that of 1999 (table 1).

The U.S. Geological Survey (USGS) developed domestic potash data from voluntary semiannual surveys of U.S. operations. Of the seven survey requests sent to operations for both semiannual surveys, six operations responded. Data were estimated for the nonrespondent for both surveys. Data from the responding sites were estimated to represent about 98% of the total production listed in table 1.

Four U.S. companies produce potash in three States. Most of the domestic production was from southeastern New Mexico, where two companies operated three mines. The other two States with potash production were Michigan and Utah. One New Mexico producer also owned a Utah surface brine operation and a deep solution mine in Michigan. Potash producers in the United States produced KCl, SOP, and SOPM. Potassium nitrate was manufactured in the United States, but output is not reported in this publication because it is a manufactured material rather than a mined material. Because all four companies produced standard and granular MOP, prices for those products were reported. All of the domestic production of SOP and SOPM, together known as sulfates, came from a single company, which prevents publishing data that could reveal or allow calculation of sulfates production, sales, or stocks.

Domestic potash sales were essentially unchanged (as K_2O) from that of 1999 owing to a moderate rise in apparent consumption, a moderate rise in imports, and a moderate decline in exports.

IMC Kalium Ltd. of IMC Global Inc. produced MOP, SOP, and SOPM in Carlsbad, NM, at the operation that started in 1940 and now includes the former Western Ag-Mineral Mine property. It also produces MOP from the Hersey, MI, solution-mine and plant and SOP from the brines of Great Salt Lake near Ogden, UT. In Carlsbad, IMC Global's new SOPM processing plant was operating with ore from its original leases and the former Western Ag-Mineral leases. It was built near an older mine shaft with its own ore hoisting facility and a separate underground conveyor belt. Only SOPM ore was hoisted up this shaft, and only sylvinite (KCl ore) was hoisted up the original shaft. Mississippi Potash, Inc., a subsidiary of Mississippi Chemical Corp., produced MOP from two potash operations near Carlsbad, known as Mississippi Potash East and Mississippi Potash West. Mississippi Potash, Inc., also operated the augmented compacting facility at the former National Potash Co. mill site known as Mississippi Potash North to convert standard MOP to granular MOP for its market.

In Utah, Reilly-Wendover Division's near-surface brine operation of Reilly Industries, Inc., continued production of MOP and manure salts. The Moab Salt, LLC, solution mine and mill continued production of MOP and table salt for Intrepid Mining, LLC, of Denver, CO. IMC Kalium Ogden Corp. continued to produce SOP from brines of Great Salt Lake through the use of solar evaporation ponds and some beneficiation in the adjacent plant. IMC Kalium Ogden's operation was offered for sale along with IMC Chemicals and IMC Salt in the middle of the year (North American Minerals News, 2000b).

In Michigan, IMC Potash Hersey Inc. operation produced white MOP from deep wells (deeper than 2,000 meters) and solution mining through mechanical evaporators and crystallizers.

The fertilizer industry has joined the latest electronic age time-saver technology with the initiation of business-to-business relationships. There are at least two such groups (Rooster.com and planetAG.com) in the United States and another forming in Germany (mySAP.com). At home, on their computers, farmers can "...market their crops, and buy their seed, fertilizers, crop protection products, equipment[,] and other supplies" (Green Markets, 2000d).

Consumption

The apparent consumption of potash for 2000 in the United States was estimated to have increased by less than 5% from that of 1999 to about 5.6 million metric tons (Mt). In 2000, as in several other years, the variation in demand for potash in the United States was controlled by forces other than the direct demand for domestic or exported farm crops, especially grain crops, or the relatively moderate price of potash. As the price rise of natural gas drove up the price of fixed nitrogen fertilizers and nitrogen/phosphate fertilizers, sales and application of these natural-gas-based fertilizers suffered. Since the three fertilizers have to be balanced in the soil for the most profitable investment for crop production, potash sales did not rise as much as they might have.

Fertilizer is an input into agriculture, and a reasonable description of potash demand can be given through the largest crops, which are corn for grain, soybeans for beans, and sorghum, rice, and cotton of all types. Corn, soybeans, and cotton showed increased planted area in 2000, up by a few percent compared with that of 1999, and area harvested was up by a few percent with yield and production increased by a few percent (National Agricultural Statistics Service, 2000, p. 4-5, 7, 10-11; 2001b, p. 1). Average corn yield was the second best yield rate on record, and total production was the second highest on record. Domestic corn consumption was boosted by two end uses: the increased production of ethanol owing to the increased domestic price of gasoline, and the increased exports of prepared meats, from cattle, pork, and poultry fed on domestic grains. The prepared meat markets—beef and pork to

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Japan and chicken to Hong Kong and Russia—rose owing to the Asian Pacific Basin's return to financial health and the increase of Russia's consumer demand for meat. Corn exports declined but to a lesser extent owing to lower corn production in China, Eastern Europe, North Africa, and the Middle East due to adverse weather. Ending corn stocks in the United States were up by nearly 6% to 216.4 Mt (National Agricultural Statistics Service, 2001c, p. 1, 5). Soybean production for beans was the highest on record (National Agricultural Statistics Service, 2001a, p. 10), soybean exports soared nearly 17% (Economic Research Service, 2001), and ending U.S. soybean stocks were up by about 2.6% (National Agricultural Statistics Service, 2001c, p. 5). The wheat-of-all-types planted area was unchanged from 1999, and area harvested decreased by 1.5%, while yield per hectare declined by 1.7% owing to dry weather in the southern plains, amounting to a 3.3% decline in production, the only yield-declining major crop in 2000 (National Agricultural Statistics Service, 2001b, p. 1, 5). Wheat exports declined by about 2% (Economic Research Service, 2001, p. 2). Ending U.S. wheat stocks (all wheat in all positions) declined by 4.4% to 49 Mt (National Agricultural Statistics Service, 2001c, p. 1, 5). U.S. grain exports were lower except for soybeans and sorghum (Economic Research Service, 2001, p. 2-3). Sorghum and rice production declined in 2000 by 21% and 7%, respectively (National Agricultural Statistics Service, 2001b, p. 14). Cotton yield increased about 4% per acre and production increased by about 1.5% (National Agricultural Statistics Service, 2000, p. 10-11; 2001b, p. 10). Cotton and cotton linters exports increased by more than double (Economic Research Service, 2001, p. 4).

Mexico was reported to be an important importer of U.S. wheat, corn, soybeans, and cotton owing to its increased earnings from the elevated price of oil. For U.S. agricultural exports, Mexico was reported to be the second largest receiver, with Japan being the largest, in agricultural bulk commodities, and fourth for high-value products (Economic Research Service, 2001, p. 5). [High value products are all agricultural products minus bulk commodities.]

Generally, potash demand was up slightly but without a clear agricultural commodity or an importing country that made a large difference. The farmers produced more corn, cotton, and soybeans using a lesser amount of potash, which might mean that genetically modified seed was more efficient at using the agricultural inputs, such as acreage, fertilizer, rain, etc., than unmodified seed.

All U.S. grain prices were relatively low, but "[d]irect government payments to farmers rose from [less than] $8 billion in 1997 to a record $22 billion last year [2000]" (Collins, 2001).

According to Potash & Phosphate Institute data, agricultural MOP shipments from Canadian and U.S. producers to the major destination by State, in decreasing order of tonnage, were Illinois, Iowa, Indiana, Ohio, Missouri, Minnesota, Wisconsin, Michigan, Florida, and Tennessee (table 3). These 10 States received 65% of agricultural sales of MOP from Canadian and United States producers in 2000. For agricultural and nonagricultural MOP shipments from Canadian and United States producers, the major receiving States, in decreasing order, were Illinois, Ohio, Iowa, Indiana, Alabama, Wisconsin, Missouri, Minnesota, Michigan, and Florida. These 10 States received about 64% of agricultural and nonagricultural sales of MOP in 2000.

The major destinations for agricultural MOP shipments from U.S. producers, in decreasing order, were Texas, Missouri, Michigan, California, Illinois, Kansas, Nebraska, and Iowa. These eight States consumed about 80% of the MOP from domestic producers. For agricultural and nonagricultural MOP sales from U.S. producers, the major receiving States, in decreasing order, were Texas, Missouri, Michigan, California, Illinois, Mississippi, Kansas, Iowa, Nebraska, and New Mexico. These 10 States received about 80% of U.S.-produced agricultural and nonagricultural MOP.

Foreign Trade

Based on U.S. Census Bureau data, as modified by the USGS, the exports of all types and all grades of potash decreased by 20% to 367,000 metric tons (t) from 459,000 t in 1999 (table 6). Exports of MOP totaled about 49% of all potash exports, SOPM totaled about 27%, SOP totaled about 21%, and potassium nitrate totaled about 3%. Latin America received about 64% of all exports, the Pacific Basin received about 25%, with the remaining 11% distributed among Africa, Canada, Europe, and the Middle East.

U.S. MOP exports fell by 36% to 181,000 t from the 1999 total of 282,000 t. MOP exports decreased by 32% to Latin America, 98% to Europe, and 21% to the Pacific Basin. SOP exports increased by about 12% to 78,000 t from 68,000 t with stronger first half-year sales. SOP exports to the Pacific Basin rose by 76% to 43,000 t, and SOP exports to Latin America fell by 8% to 35,000 t. The Pacific Basin received about 55% of total SOP exports, while Latin America received about 45%. Total exports of SOPM were essentially unchanged from last year, with Canada increasing its imports by 27%, and imports to Latin America and the Pacific Basin declining by about 14% and about 4%, respectively.

Potash imports into the United States increased by about 3% compared with those of 1999 to about 4.6 Mt (tables 8, 9). MOP imports from Belarus, Canada, and Russia increased slightly. SOP imports from Canada, Chile, and Germany decreased. Potassium nitrate imports from Chile nearly doubled. MOP accounted for nearly 99% of total imports, and Canada supplied about 94% of the MOP imports.

Transportation

The U.S. Surface Transportation Board (STB) held hearings on the proposed merger of Burlington Northern and Santa Fe Railway Co. with Canadian National Railway Co., Grand Trunk Western Railroad Inc., and Illinois Central Railroad Co. The STB then put all mergers on hold because of railroad freight customers concerns that another large merger would again bring traffic to slow motion after the experience of the previous merger of the Union Pacific and Southern Pacific Railroads in 1997 and 1998 (Green Markets, 2000e) and the problematic division of Consolidated Railroad Corp. (CONRAIL) into a section for Norfolk Southern Corp. and a section for CSX Corp. in 1999.

A new bulk fertilizer terminal in the sea port of St. Petersburg, Russia, has been proposed with the help of the joint stock corporation (JSC) Uralkali of Berezniki, Perm, Russia (Fertilizer Week, 2000d).

World Review

Estimated world potash production for 2000 declined by

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about 1% from that of 1999 (table 10). European production was down by 1% with production in Germany and Spain decreasing and production in France and the United Kingdom increasing. In the former Soviet Union, production declined by about 9% compared with 1999 production. North America showed about a 4% increase, primarily from a production increase in Canada. Israel and Jordan, combined, reported an increase of less than 2% from that of 1999.

Canada.—Canpotex Ltd. reported an agreement with JSC Uralkali to form a joint marketing arrangement primarily in the Asian Pacific market but not in North America or Europe. (Fertilizer Markets, 2001; Potash Corp. of Saskatchewan, 2000; 2001a). Canpotex Ltd. sells offshore for the Saskatchewan operations of the three Canadian potash producers.

Chile.—In early 2000, Atacama Minerals Corp. decided to stockpile potassium nitrate ore while producing iodine. Potassium nitrate production was delayed for 6 years. Atacama Minerals estimated that world potassium nitrate consumption in 2000 was 450,000 metric tons per year (t/yr) with another 180,000 t/yr capacity starting up in Chile in the next 5 years (North American Minerals News, 2000a). Late in the year, another potassium nitrate producer, Compania de Salitre y Yodo, which already had a mine and mill at Pozo Almonte in northern Chile, announced a November startup of 90,000 t/yr capacity, using Canadian and Russian MOP as feedstock (Fertilizer Week, 2000a). The company mentioned plans for future iodine production.

China.—The Qarhan Lake potash project in Qaidam Basin of the Qinghai Province had been a joint venture between unnamed Chinese companies with Israel's Dead Sea Works Ltd. (DSW) and United Development Industries Co. (UDI) since 1993. They attempted to raise money as the Chinese Israeli Potash Co. (Cipco) in 1994 (European Chemical News, 1994). In 1998, the fundraising effort was the joint venture of Mingda Chemical Mines Co., DSW, and UDI (Fertilizer Week, 2000c) or Minda Chemical Corp. (Industrial Minerals, 2000b). In 2000, China seems to have taken control over the development at this site with a MOP project with reduced capacity of 180,000 t/yr under the name Qinghai Salt Lake Industry Group (Fertilizer Week, 2000b). Simultaneously, the Chaerhan Salt Lake Group has apparently commenced development of a MOP lake brine project near the city of Golmud in Qaidam Basin (Fertilizer Week, 2000c). Another joint venture, with the name of Lop Nor Sylvite Co., Ltd., in the Xinjiang Uyghar Autonomous Region, west of Qinghai Province, announced that it was working to develop MOP as an intermediate for producing SOP and potassium nitrate from the Lop Nor interior basin. The partners for this group are Sanwei Mining Co., the Xinjiang Delong Group Co., the Xinjiang Hami Gold Mine, and Xinjiang Nonferrous Metals Industrial Co., a regional government arm (Green Markets, 2000f).

Israel.—Haifa Chemicals Ltd. announced in May a 50% reduction in production to 67,500 t/yr of KNO_3 at the Haifa plant owing to world market conditions (Green Markets, 2000c). Haifa Chemicals reportedly has about 65% of world capacity and is owned by the U.S. company Trans-Resources, Inc. Haifa Chemicals opened talks with Israel Chemicals Ltd. for possible methods of cooperation (Green Markets, 2000b). There was a conflict between tourism and mineral sales at Eilat Port where dust from loading ships reached the hotels in the city. The Government of Israel operates the ports and has not invested in dust-free shiploading equipment, so it sought to shut down loading during tourist season. MOP would leave through this port towards the Asian markets (Green Markets, 2000a). DSW announced plans to increase MOP production by 0.36 Mt to 2.76 Mt (Green Markets, 2000g).

Russia.—JSC Uralkali Ltd., which operates the Berezniki plants in the Perm region, shipped some product through Fedcominvest in the early part of the year and through International Potash Co. in the latter part of the year, then sought a partnership with Canpotex International, Ltd., for 2001. JSC Uralkali had also started on the construction of a potash dock at the JSC St. Petersburg seaport, which is served by broad gauge rail, to replace the insufficient storage space at the port of Ventspils and to avoid the change of track gauge to standard gauge. JSC Uralkali had also chosen the Finnish port of Kotka, which is also served by broad gauge railroad tracks from mine to dock and is deep enough to handle panamax ships (Fertilizer Markets, 2001).

Spain.—Iberpotash S.A., which is the new name of the former Grupo Potasas, became majority-owned by DSW as of 1998 and is now 100% owned by DSW (Dead Sea Works Ltd., [undated], Iberpotash S.A.—Spain, accessed July 24, 2001, at URL http://www.dsw.co.il/iberp.htm). DSW announced plans to increase Spanish MOP capacity by about 12.5% or by 90,000 t/yr to 810,000 t/yr, but no timetable was given (Green Markets, 2000). Comercial de Potasas, S.A., the sales arm of Iberpotash, agreed to handle DSW potash sales into France, Portugal, and Spain (Industrial Minerals, 2000a). DSW has traditionally sold into those three countries because it ships from Ashdod on the eastern end of the Mediterranean Sea and sails past the French, Portuguese, and Spanish ports on the way to ports in the United States and Latin America.

Outlook

In the short to intermediate term, domestic potash consumption is likely to continue to vary within a 21-year historical band with a mean of 5.5 million metric tons per year (Mt/yr). That has been a band between 4.5 and 6.45 Mt/yr. There may be a slight downward trend as less potash will probably be needed for the same harvested areas owing to less weed competition in the fields for some crops. U.S. production is expected to remain relatively steady, and imports of potash will dominate the total supply. Demand should vary with U.S. food consumption and exports of U.S. farm crops and domestically fed meat products. Variations in demand come from combinations of weather pattern changes, national or regional (multinational) economy variations, and political decisions. On the world supply side, the world's largest potash producers are expected to continue to withhold some capacity from the world market for another year. The short- to intermediate-term outlook for world wide potash consumption is that more potash should be consumed in Asian and Latin American countries to balance out the fertilizer application rates and produce more crops per acre; European consumption might decline. The Government of Russia, or international organizations, will probably help Russian farmers purchase fertilizers to increase productivity per hectare so that Russia could become self-sustaining in food production. Some African nations will need international help to purchase potash-bearing fertilizers to achieve higher crop productivity. Over the long term, worldwide, more potash will be needed to feed a growing population.

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References Cited

Collins, Keith, 2001, U.S. farm economy in 2001: Agricultural Outlook, Economic Research Service, U.S. Department of Agriculture, AGO-280, April, p. 2-6.

Economic Research Service, 2001, U.S. agricultural trade update: U.S. Department of Agriculture, FAU-50, February 28, 7 p.

European Chemical News, 1994, In brief: European Chemical News, May 2, p. 29.

Fertilizer Markets, 2001, Canpotex makes moves to fit in Uralkali sales: Fertilizer Markets, v. 11, no. 23, January 12, p. 2.

Fertilizer Week, 2000a, Chile's Cosayach set for KNO_3 startup: Fertilizer Week, v. 14, no. 27, November 13, p. 1.

———2000b, Qinghai goes it alone on potash plan: Fertilizer Week, v. 14, no. 31, December 11, p. 1-2.

———2000c, Qinghai K plan revised; DSW role in doubt: Fertilizer Week, v. 13, no. 45, March 27, p. 1.

———2000d, Uralkali in K terminal plan for St. Petersburg: Fertilizer Week, v. 14, no. 28, November 20, p. 2.

Green Markets, 2000a, Fertilizer movement out of Israeli port threatened: Green Markets, v. 24, no. 25, June 19, p. 9

———2000b, Haifa, Israel Chem discuss cooperation: Green Markets, v. 24, no. 8, February 21, p. 10.

———2000c, Haifa to reduce potassium nitrate levels: Green Markets, v. 24, no. 22, May 29, p. 10.

———2000d, Industry giants hope farmers will flock to Rooster.com: Green Markets, v. 24, no. 10, March 6, p. 1.

———2000e, Merger-weary stakeholders express views to Surface Transportation Board–Congressional officials seek moratorium on real mergers: Green Markets, v. 24, no. 11, March 13, p. 1.

———2000f, Potash–China: Green Markets, v. 24, no. 39, September 25, p. 8.

———2000g, Potash–Israel: Green Markets, v. 24, no. 27, July 10, p. 8.

Industrial Minerals, 2000a, Copsa/DSW potash sales agreement: Industrial Minerals, no. 390, March, p. 23.

———2000b, Qinghai potash uncertain: Industrial Minerals, no. 395, August, p. 85.

National Agricultural Statistics Service, 2000, Crop production: U.S. Department of Agriculture, PCP-BB, October, 42 p.

———2001a, Crop production: U.S. Department of Agriculture, PCP-BB, February, 47 p.

———2001b, Crop production 2000 summary: U.S. Department of Agriculture, PCP-BB, January, 93 p.

———2001c, Grain stocks: U.S. Department of Agriculture, PGS-BB, January, 34 p.

North American Mineral News, 2000a, Atacama details Aguas Blancas nitrate/sulfate plans: North American Mineral News, no. 58, March, p. 3.

———2000b, IMC retains Chase to explore salt sale: Industrial Minerals, no. 58, March, p. 1.

Potash Corp. of Saskatchewan, Inc., 2000, PCS announces joint marketing arrangement between Canpotex and Russian potash producer, JSC Uralkali: Potash Corp. of Saskatchewan, Inc., news release, April 20, 1 p.

———2001a, Form 10-K–2000: Securities and Exchange Commission, p. 24.

———2001b, PCS announces finalization of joint marketing arrangement between Canpotex and Russian potash producer, JSC Uralkali: Potash Corp. of Saskatchewan, Inc., news release, January 5, 1 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Potash. Ch. in Mineral Commodity Summaries, annual.

Potash. Mineral Industry Surveys, Crop year (July 1-June 30), annual.

Other

Annual Fertilizer Review. United Nations, Food and Agricultural Organization, Rome, annual.

European Chemical News. Reed Business Publishing Ltd., Surrey, England, weekly.

Fertilizer International (includes Phosphorous & Potassium). CRU Publishing Ltd., London, bimonthly.

Fertilizer Focus. FMB Publications Ltd., Middlesex, England, monthly.

Fertilizer Markets. British Sulphur North America Inc., weekly.

Green Markets. Pike & Fischer Publications, weekly.

Industrial Minerals, Industrial Minerals Information Ltd., of Metal Bulletin plc, London, monthly.

Potash. Ch. in Canadian Minerals Yearbook, Natural Resources Canada, Mining Sector, Ottawa, Canada, annual.

Potash Resources. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.

Supply-Disappearance Statistics. Potash & Phosphate Institute, Norcross, GA, monthly, quarterly, and annual.

World Fertilizer Review. Fertecon Ltd., London, monthly.

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TABLE 1
SALIENT POTASH STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production	2,890	2,900 3/	3,000 3/	2,500 3/	2,600 3/
K_2O equivalent	1,390	1,400 3/	1,300 3/	1,200 3/	1,300 3/
Sales by producers	2,960	3,000 3/	2,900 3/	2,500 3/	2,600 3/
K_2O equivalent	1,430	1,400 3/	1,300 3/	1,200 3/	1,200 3/
Value 4/	$299,000	$320,000 5/	$330,000 5/	$280,000 5/	$290,000 5/
Average value of product dollars per metric ton	$101.08	$110.00 6/	$115.00 6/	$110.00 6/	$110.00 6/
Average value of K_2O equivalent do.	$208.57	$230.00 6/	$250.00 6/	$230.00 6/	$230.00 6/
Exports	1,100	1,070	1,130	1,080	923
K_2O equivalent	481	466	477	459	367
Imports for consumption 7/ 8/	8,140	9,030	7,870	7,360	7,580
K_2O equivalent	4,940	5,490	4,780	4,470	4,600
Customs value	$563,000	$610,000	$648,000	$566,000	$555,000
Consumption, apparent 9/	10,000	11,000 3/	9,700 10/	8,700 10/	9,400 10/
K_2O equivalent	5,890	6,500 3/	5,600 10/	5,100 10/	5,600 10/
World, production of marketable K_2O equivalent	23,300	25,200	25,900 r/	25,600 r/	25,400 e/

e/ Estimated. r/ Revised.

1/ Includes muriate and sulfate of potash, potassium magnesium sulfate, and some parent salts. Excludes other chemical compounds containing potassium.

2/ Data are rounded to no more than three significant digits, unless otherwise specified, except prices.

3/ Data rounded to within 100,000 tons to avoid disclosing proprietary data.

4/ F.o.b. mine.

5/ Data are rounded to no more than two significant digits.

6/ Rounded to the nearest $5 to avoid disclosing proprietary data.

7/ Excludes potassium chemicals and mixed fertilizers.

8/ Includes nitrate of potash.

9/ Calculated from sales plus imports minus exports.

10/ Data rounded to within 200,000 tons to avoid disclosing proprietary data.

TABLE 2
PRODUCTION OF CRUDE ORE IN NEW MEXICO

(Thousand metric tons)

	Crude salts 1/ (mine production)	
Period	Gross weight	K_2O equivalent
1999:		
January-June 2/	6,000	700
July-December 2/	6,000	700
Total	12,000	1,400
2000:		
January-June 2/	6,000	700
July-December 2/	6,000	700
Total	12,000	1,400

1/ Sylvinite and langbeinite.

2/ Data are rounded to no more than one significant digit.

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TABLE 3
SALES OF NORTH AMERICAN MURIATE OF POTASH, BY STATE OF DESTINATION 1/

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	1999	2000	1999	2000
Alabama	78,100	86,400	239,000	220,000
Alaska	4,180	986	1,950	5,020
Arizona	4,230	3,700	2,340	1,950
Arkansas	66,000	84,100	290	183
California	85,200	75,700	15,800	15,400
Colorado	15,200	15,300	1,660	1,820
Connecticut	2,050	1,890	2,380	1,590
Delaware	24,400	21,700	49,600	46,800
Florida	146,000	153,000	12,700	12,900
Georgia	124,000	131,000	741	1,100
Hawaii	--	370	--	--
Idaho	35,600	38,000	1,020	748
Illinois	542,000	591,000	21,600	25,000
Indiana	329,000	369,000	7,060	11,100
Iowa	351,000	386,000	4,160	4,490
Kansas	34,000	35,200	8,010	8,270
Kentucky	113,000	115,000	7,620	8,750
Louisiana	72,900	110,000	3,980	6,090
Maine	3,530	3,380	273	225
Maryland	27,900	28,200	617	1,830
Massachusetts	2,580	1,990	6,390	7,270
Michigan	163,000	170,000	10,600	8,240
Minnesota	236,000	254,000	7,180	7,670
Mississippi	58,700	38,700	44,100	61,900
Missouri	247,000	264,000	4,330	4,460
Montana	20,500	17,800	150	167
Nebraska	44,700	59,400	1,830	1,740
Nevada	313	65	249	693
New Hampshire	383	798	294	198
New Jersey	5,560	5,480	1,000	784
New Mexico	6,560	3,990	17,700	19,600
New York	68,200	55,300	3,050	2,790
North Carolina	111,000	125,000	648	264
North Dakota	24,800	30,600	254	79
Ohio	319,000	333,000	116,000	105,000
Oklahoma	16,500	18,200	3,650	6,740
Oregon	40,200	33,600	1,920	1,630
Pennsylvania	54,800	57,400	12,200	9,220
Rhode Island	--	--	86	43
South Carolina	51,700	57,300	137	169
South Dakota	14,700	18,100	524	727
Tennessee	147,000	129,000	6,680	7,260
Texas	129,000	126,000	21,500	26,900
Utah	4,790	1,990	11,400	5,420
Vermont	4,160	3,690	591	69
Virginia	71,800	84,800	114	601
Washington	42,100	43,600	919	1,360
West Virginia	2,930	3,900	355	728
Wisconsin	223,000	214,000	68,000	68,300
Wyoming	5,120	1,800	2,420	1,580
Total	4,170,000	4,400,000	725,000	725,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Potash & Phosphate Institute.

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TABLE 4
SALES OF NORTH AMERICAN MURIATE OF POTASH
TO U.S. CUSTOMERS, BY GRADE 1/

(Thousand metric tons of K_2O equivalent)

Grade	1999	2000
Agricultural:		
Standard	246	210
Coarse	2,000	2,090
Granular	1,520	1,700
Soluble	410	407
Total	4,170	4,400
Nonagricultural:		
Soluble	125	147
Other	601	578
Total	725	725
Grand total	4,900	5,130

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Potash & Phosphate Institute.

TABLE 5
PRICES OF U.S. POTASH, BY TYPE AND GRADE 1/ 2/

(Dollars per metric ton of K_2O equivalent)

	1999		2000	
Type and grade	January-June	July-December	January-June	July-December
Muriate, 60% K_2O minimum:				
Standard	150	150	155	160
Granular	170	150	165	160

1/ Average prices, f.o.b. mine, based on sales.
2/ Data rounded to nearest $5.

TABLE 6
U.S. EXPORTS OF POTASH, BY TYPE 1/

	Approximate average K_2O content (percentage)	Quantity (metric tons)	
		Product	K_2O equivalent e/
1999:			
Potassium chloride, all grades	61	462,000	282,000
Potassium sulfate	51	134,000	68,400
Potassium magnesium sulfate	22	466,000	103,000
Potassium nitrate	45	13,500	6,080
Total	XX	1,080,000	459,000
2000:			
Potassium chloride, all grades	61	296,000	181,000
Potassium sulfate	51	153,000	78,100
Potassium magnesium sulfate	22	455,000	100,000
Potassium nitrate	45	19,000	8,570
Total	XX	923,000	367,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 7
U.S. EXPORTS OF POTASH, BY COUNTRY 1/

(Metric tons of product)

Country	Potassium chloride		Potasium sulfate, all grades		Potassium nitrate		Total	
	1999	2000	1999	2000	1999	2000	1999	2000
Argentina	2,350	3,320	14,100	19,100	--	579	16,500	23,000
Australia	70	--	4,030	4,650	--	--	4,100	4,650
Belgium	32,000	--	10	--	--	--	32,000	--
Bolivia	17,000	7,380	--	--	--	--	17,000	7,380
Brazil	70,600	25,900	1,550	1,050	153	1	72,300	26,900
Canada	3,830	5,860	74,100	97,800	7,550	6,910	85,500	111,000
Chile	79	25,400	52,900	28,800	--	--	52,900	54,200
China	--	--	5	40,200	--	--	5	40,200
Colombia	17,000	7,390	55,200	33,000	--	--	72,200	40,400
Costa Rica	3,670	2,230	50,200	42,500	--	--	53,900	44,800
Dominican Republic	33,500	16,300	10,600	2,490	39	45	44,100	18,800
Ecuador	--	6	8,460	17,400	20	139	8,480	17,500
France	--	41	15	10,300	--	--	15	10,400
Guatemala	12,800	--	13,300	5,820	--	120	26,100	5,940
Honduras	190	241	2,240	12,200	--	200	2,430	12,600
Italy	38	--	--	--	--	--	38	--
Ivory Coast	6,170	3,150	12,500	--	--	--	18,600	3,150
Jamaica	15,700	12,100	20	--	136	2,090	15,800	14,200
Japan	23,000	27,000	137,000	125,000	2	2	161,000	152,000
Korea, Republic of	--	--	20,600	15,300	3	4,480	20,600	19,800
Malaysia	--	--	--	12,800	916	1,370	916	14,200
Mexico	158,000	94,500	78,400	77,800	4,440	2,800	241,000	175,000
Panama	2,120	9,050	737	1,790	--	--	2,850	10,800
Peru	465	--	13,800	11,200	--	--	14,300	11,200
South Africa	11,500	--	--	3,970	--	--	11,500	3,970
Thailand	--	--	3,520	2,870	--	--	3,520	2,870
Venezuela	13,700	30,200	13,600	25,100	--	--	27,300	55,300
Other	39,000	26,100	33,100	16,600	255	310	72,300	43,000
Total	462,000	296,000	601,000	608,000	13,500	19,000	1,080,000	923,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes potassium magnesium sulfate.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY TYPE 1/

	Approximate average K_2O content (percent)	Quantity (metric tons)		Value (thousands)	
		Product	K_2O equivalent e/	Customs	C.i.f.
1999:					
Potassium chloride 2/	61	7,230,000	4,410,000	$539,000	$573,000
Potassium sulfate	51	86,000	43,900	18,800	20,800
Potassium nitrate	45	21,200	9,550	6,310	6,980
Potassium sodium nitrate mixture	14	15,700	2,200	2,590	2,970
Total	XX	7,360,000	4,470,000	566,000	604,000
2000:					
Potassium chloride 2/	61	7,450,000	4,550,000	525,000	548,000
Potassium sulfate	51	74,800	38,200	16,100	17,300
Potassium nitrate	45	40,900	18,400	11,900	13,700
Potassium sodium nitrate mixture	14	9,360	1,310	1,540	1,660
Total	XX	7,580,000	4,600,000	555,000	581,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Contains imports listed under Harmonized Tariff Schedule of the United States code 3104.10.0000.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY COUNTRY 1/

Country	Potassium chloride (metric tons)		Potassium sulfate (metric tons)		Potassium nitrate (metric tons)		Potassium sodium nitrate (metric tons)		Total (metric tons)		Total value (thousands)			
											Customs		C.i.f.	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Belarus	106,000	135,000	--	--	--	--	--	--	106,000	135,000	$8,970	$11,400	$10,100	$12,900
Belgium	--	--	22	22	--	--	--	--	22	22	4	10	6	14
Bulgaria	--	1,000	--	--	--	--	--	--	--	1,000	--	85	--	100
Canada	6,880,000	7,020,000	21,800	17,900	5	5	102	136	6,900,000	7,040,000	513,000	492,000	544,000	511,000
Chile	--	50	10,600	7,840	17,800	34,900	15,600	9,190	44,000	52,000	9,070	12,400	10,200	14,000
China	--	--	187	1	--	--	--	--	187	1	15	9	15	9
Denmark	--	--	--	--	687	3,080	42	--	729	3,080	297	1,090	365	1,410
Germany	37	269	52,900	48,800	167	336	22	30	53,100	49,400	11,000	10,200	12,200	10,800
India	--	--	--	--	69	344	--	--	69	344	38	114	43	124
Israel	--	60	--	--	946	846	--	--	946	906	364	339	447	412
Japan	--	2	489	294	1,400	1,060	--	--	1,890	1,350	954	674	1,080	760
Mexico	--	--	--	--	2	4	--	--	2	4	4	7	5	7
Netherlands	--	--	--	4	34	--	--	--	34	4	21	2	24	2
Poland	--	--	--	--	72	93	--	--	72	93	45	46	50	57
Russia	251,000	296,000	--	--	--	--	--	--	251,000	296,000	21,900	25,200	25,100	28,300
United Kingdom	827	984	--	--	--	1	--	--	827	985	220	463	241	564
Other 2/	1	70	63 r/	20	31 r/	260	--	--	95 r/	350	48 r/	114	52 r/	140
Total	7,230,000	7,450,000	86,000	74,800	21,200	40,900	15,700	9,360	7,360,000	7,580,000	566,000	555,000	604,000	581,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Potassium chloride includes France (2000), Slovakia (2000), Spain (2000), and Switzerland (1999); potassium sulfate includes the Dominican Republic (2000) and France (1999); potassium nitrate includes the Dominican Republic (2000), Finland (2000), Italy (2000), Spain (1999), and Switzerland (1999).

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 10
MARKETABLE POTASH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of K_2O equivalent)

Country	1996	1997	1998	1999	2000 e/
Belarus	2,716	3,247 r/	3,451 r/	3,600 e/	3,400
Brazil	243	280	326	350 e/	350
Canada	8,120	8,989	9,201	8,329	8,600
Chile	21	22	22	22 e/	23
China e/	110	115	120	150 r/	250
France	751 e/	725	656	311 r/	321
Germany	3,332	3,423	3,581	3,545 r/	3,409 3/
Israel	1,500 e/	1,488	1,668 r/	1,702 r/	1,710
Jordan	1,080 e/	868	910 e/	1,080 r/	1,110
Russia e/	2,620 r/	3,400	3,500	4,200	3,700
Spain e/	717	640	497 r/ 3/	550	522 3/
Ukraine e/	76	60 3/	35	35	30
United Kingdom	618	565	608	495 r/	600
United States	1,390	1,400 4/	1,300 4/	1,200 4/	1,300 4/
Total	23,300	25,200	25,900 r/	25,600 r/	25,400

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 27, 2001.

3/ Reported figure.

4/ Rounded to within 100,000 tons to avoid disclosing proprietary data.

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PUMICE AND PUMICITE

By Wallace P. Bolen

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2000, pumice and pumicite consumption in the United States was 1.06 million metric tons (Mt). This consumption was about 9% greater than that of 1999 and represents the highest level of pumice consumption since 1979, when 1.12 Mt was consumed. The increase in consumption was attributable to greater domestic sales and increased imports of pumice and pumicite primarily for formed lightweight concrete products. Domestic production increased by about 8%, and exports, while still small relative to total domestic consumption, increased by about 17% (table 1).

The main use for pumice was as an aggregate in lightweight building blocks and assorted building products. Other major applications for pumice and pumicite included abrasive, absorbent, concrete aggregate and admixture, filter aid, horticulture (including landscaping), and the stonewashing of denim.

Production

Pumice and pumicite sold or used by U.S. producers increased to 697,000 metric tons (t) valued at $16.9 million (table 1). Oregon remained the leading source of pumice and pumicite, followed, in descending order, by California, New Mexico, Idaho, Arizona, and Kansas. Domestic production data for pumice and pumicite were developed by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations. In 2000, 15 companies with 16 active operations produced and sold or used all the domestic pumice and pumicite in the United States. Because four of the companies did not respond to the 2000 survey, sold and used data for these companies were estimated. The 11 companies that responded represented about 81% of the 697,000 t.

Domestic producers, listed alphabetically by State, were Tufflite Inc., Phoenix, AZ; California Industrial Minerals Co., Friant, CA; California Lightweight Pumice, Inc., San Clemente, CA; Glass Mountain Pumice Inc., Tulelake, CA; U.S. Pumice Co., Chatsworth, CA; Amcor Precast, Inc., and Producers Pumice, Idaho Falls, ID; Hess Pumice Products, Inc., Malad City, ID; Calvert Corp., Norton, KS; Kansas Minerals Inc., Mankato, KS; Copar Pumice Co, Inc., Espanola, NM; CR Minerals Corp., Santa Fe, NM; Utility Block Co., Albuquerque, NM; Cascade Pumice Co., Bend, OR; and Sierra Cascade LLC, Chemult, OR.

Consumption

The amount of pumice and pumicite sold or used by U.S. producers rose in 2000 because of increased demand exclusively from the building block and concrete markets (table 2). Demand declined for all other uses except horticultural (including landscaping) applications, which remained at 1999 levels. The amount of pumice sold for building block increased by about 20%, to 470,000 t from 391,000 t. Sales of pumice and pumicite for abrasives, laundries (stonewashing), and miscellaneous markets decreased in 2000 compared with those of 1999. Sales of domestic stonewashing (or laundry) grade pumice continued to decrease following a trend that began in 1997. Sales fell to 6,000 t in

Pumice and Pumicite in the 20th Century

The production of pumice and pumicite in the United States, which started in 1897 with the shipment of 143 metric tons from mines in Nebraska and South Dakota and had increased to more than 544 tons in 1898, had practically ceased by 1900. Because of the distance of these deposits from the railroad and from large markets, domestic producers were not able to compete with pumice imported from Italy. Italian pumice was brought in as ballast in ships and therefore was inexpensively shipped. Italian pumice sold in New York for 4.4 to 6.25 cents per kilogram. About 80% of the domestic demand for pumice was supplied from Lapari, a small island north of Sicily. The Bureau of Statistics of the Department of Treasury kept no record of the amount of pumice imported but the data the Bureau of Statistics kept on the value of pumice imported listed the annual value of imports between $43,000 and $65,000 for the period between 1893 and 1899. Pumice was crushed and bolted for drying and used in the manufacture of various polishing powders and scouring stones.

By 2000, 385,000 tons of pumice and pumicite valued at about $14 million was imported, mostly from Greece. The main use for pumice in 2000 was as a lightweight aggregate in variously shaped and sized concrete building and decorative blocks. Pumicite was mostly used in filtration and in abrasives. Abrasive uses consumed only a small percentage of the pumice and pumicite. Pumice mining in the United States was concentrated in California, Idaho, New Mexico, and Oregon; 16 mines in the Western United States produced and sold or used nearly 700,000 tons. Domestic producers continued to suffer a transportation disadvantage when trying to ship to the Eastern United States, making it possible for imports to supply many of the markets from the Great Lakes region to the Gulf Coast.

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2000 from 16,000 t in 1999, which represents a decrease of about 63%.

The most important market for pumice remained building block, which consumed 67.4% of the total pumice sold or used in the United States. Other important uses were horticulture and landscaping (14.3%), concrete aggregate (6.6%), and abrasives (3.7%). The remaining pumice and pumicite (8%) was used as absorbent (including pet litter), diluents, fill, filter aids, in laundries, in pottery clays, and for other unspecified uses.

Prices

The average prices reported for pumice and pumicite varied greatly by use compared with the average price for all uses in 2000. The overall average price was $24.27 per metric ton in 2000, a decrease of $3.42 from $27.69 per ton in 1999. The price change was primarily the result of a decrease in the average price reported for the grades of pumice used in building block. This decrease in price more than offset increases in the average prices for abrasives, concrete aggregate, and miscellaneous uses. Average prices per ton for pumice and pumicite by use, in descending order, were $215 for abrasive, $110 for stone washing, $38 for concrete admixture and aggregate, $29 for horticulture/landscaping, $20 for miscellaneous uses, and $11 for building block.

Foreign Trade

Exports of pumice increased to 27,000 t with a value of $15.3 million. Importing countries were led by Canada (29%), Japan (18%), Germany (9%), Malaysia (8%), Mexico (7%), Brazil (5%), and the United Kingdom (5%). The remaining 19% of exports went to 32 other countries in Asia, Central America, Europe, the Middle East, Oceania, and South America.

By volume, most imports of pumice and pumicite were for construction-related uses with smaller amounts used for abrasives and stonewashing. Greece remained the largest source of pumice imports, supplying more than 79% (table 3). In 2000, imports increased by about 8% to 385,000 t compared with that of 1999. Imports from Greece increased by 6% to 305,000 t, while imports from Italy nearly doubled to about 60,000 t compared with those of 1999. Imports from Mexico and Turkey were about the same as in 1999. In addition to these countries, 12 other countries exported pumice and pumicite to the United States in 2000.

World Review

The USGS estimated world pumice (and related materials) production at 12 Mt in 2000, about the same as in 1999 (table 4). Most of the data published were provided by official government agencies in each country. Large revisions of data are reported by these agencies usually without supporting explanations. Globally, Italy remained the dominant producer of pumice and pozzolan, with production estimated to be 4.6 million metric tons per year. Other leading countries in the production of pumice and related materials were Chile, Ecuador, Ethiopia, France, Germany, Greece, Spain, Turkey, and the United States. In addition, at least 16 other countries produced pumice.

Pumice is used more extensively outside of the United States, which helps to explain the large global production and sales of pumice relative to the United States. In Europe, for example, basic home construction uses significantly less gypsum sheetrock, stone and concrete being usually the preferred building materials. Prefabricated lightweight concrete walls are often produced and shipped to construction locations. Because of its lightweight, strength, and cementitious properties, pumice performs very well in the European style of construction.

Outlook

Consumption of pumice and pumicite in 2001 should stay at about 2000 levels, because construction activity is expected to slow down with the cooling economy. Imports and exports are expected to increase slightly from 2000 levels in 2001.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Lightweight Aggregates. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Pumice and Pumicite. Ch. in Mineral Commodity Summaries, annual.

Other

Bates, R.L., 1969, Geology of the Industrial Rocks and Minerals: New York, Dover Publications Inc., p. 39-50.
Industrial Minerals Magazine (London).

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TABLE 1
SALIENT PUMICE AND PUMICITE STATISTICS 1/

(Thousand metric tons and thousand dollars, unless otherwise specified)

		1996	1997	1998	1999	2000
United States, sold and used by producers:						
Pumice and pumicite		612	577	583	643	697
Value 2/		$14,800	$16,100	$12,600	$17,800	$16,900
Average value	dollars per metric ton	$24.19	$27.90	$21.59	$27.69	$24.27
Exports e/		13	12	22	23	27
Imports for consumption		215	265	288	354	385
Apparent consumption 3/		814	830	849	974	1,060
World, production of pumice and related volcanic materials		11,400	11,800	12,000	12,000 r/	12,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except average value.

2/ Freight on board mine and/or mill.

3/ Production plus imports minus exports plus adjustments for Government and industry stock changes.

TABLE 2
PUMICE AND PUMICITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

	1999			2000		
Use	Quantity (thousand metric tons)	Value (thousands)	Average unit value	Quantity (thousand metric tons)	Value (thousands)	Average unit value
Abrasives 2/	31	$5,080	$163.81	26	$5,590	$215.08
Building block, includes decorative	391	5,820	14.88	470	5,080	10.81
Concrete admixture and aggregate	35	836	23.89	46	1,730	37.65
Horticulture and landscaping	100	2,860	28.56	100	2,860	28.57
Laundries	16	1,940	121.00	6	661	110.17
Other 3/	70	1,280	18.23	50	992	19.84
Total	643	17,800	27.69	697	16,900	24.27

1/ Data are rounded to no more than three significant digits, except "Average unit value;" may not add to totals shown.

2/ Includes cleaning and scouring compounds.

3/ Includes absorbent, diluents, fill, filter aids, pottery, and other unspecified uses.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF PUMICE,
BY CLASS AND COUNTRY 1/

(Thousand metric tons and thousand dollars)

	Crude or unmanufactured		Wholly or partly manufactured	
Country	Quantity	Value	Quantity	Value
1999:				
Greece 2/	299	7,030	(3/)	705
Italy	32	665	(3/)	139
Mexico	2	524	(3/)	51
Turkey	19	3,240	--	--
Other 4/	1	155	(3/)	1,100
Total	353	11,600	1	2,000
2000:				
Greece 2/	305	7,910	(3/)	225
Italy	60	651	(3/)	178
Mexico	1	186	(3/)	28
Turkey	19	3,070	--	--
Other 5/	(3/)	91	(3/)	1,380
Total	384	11,900	1	1,810

See footnotes at end of table.

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TABLE 3--Continued
U.S. IMPORTS FOR CONSUMPTION OF PUMICE,
BY CLASS AND COUNTRY 1/

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The Journal of Commerce Port Import/Export Reporting Service data.
3/ Less than 1/2 unit.
4/ Includes Austria, China, Ecuador, France, Germany, Indonesia, Japan, the Republic of Korea, the Philippines, Poland, Spain, Syria, Taiwan, Tokelau, and the United Kingdom.
5/ Includes Ausrtria, China, the Czech Republic, Ecuador, Germany, Japan, the Republic of Korea, the Philippines, Poland, South Africa, Taiwan, and the United Kingdom.

Source: U.S. Census Bureau.

TABLE 4
PUMICE AND RELATED MATERIALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Argentina 4/	81,283	147,235	140,000 e/	120,000 e/	120,000
Austria, trass e/	6,000	5,000	5,000	5,000	5,000
Burkina Faso e/	11,000	10,000	10,000	10,000	10,000
Cameroon, pozzolan e/	80,000	100,000	105,000	80,000	90,000
Cape Verde, pozzolan e/	1,000	1,000	1,000	1,000	1,000
Chile, pozzolan	500,000	491,000	912,000	600,000 e/	650,000
Costa Rica e/	8,000	8,000	8,000	8,000	8,000
Dominica, pumice and volcanic ash e/	100,000	100,000	100,000	100,000	100,000
Ecuador, pumice	231,875	368,269	320,000 e/	330,000 e/	350,000
Ethiopia e/	360,000	325,000	325,000	300,000	300,000
France, pozzolan and lapilli	410,000	477,000	460,000 e/	460,000 e/	450,000
Germany, pumice (marketable) e/	600,000	600,000	600,000	600,000	600,000
Greece:					
Pumice e/	867,450 5/	900,000	900,000	900,000	850,000
Pozzolan	749,790	841,646	850,000 e/	800,000 e/	750,000
Guadeloupe, pumice e/	210,000	210,000	210,000	210,000	210,000
Guatemala, pumice e/	64 5/	6,000	6,350	6,400	6,300
Iceland, pumice and scoria e/	25,000	25,000	25,000	25,000	25,000
Iran e/	200,000	200,000	150,000	150,000	150,000
Italy: e/					
Pumice and pumiceous lapilli	600,000	600,000	600,000	600,000	600,000
Pozzolan	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000
Macedonia, volcanic tuff e/	75,000	75,000	75,000	70,000	60,000
Martinique, pumice e/	130,000	130,000	130,000	130,000	130,000
New Zealand	90,571	196,687	190,000 e/	500,000 r/ e/	500,000
Serbia and Montenegro, volcanic tuff e/	75,000	75,000	75,000	70,000	70,000
Slovenia, volcanic tuff e/	40,000	40,000	40,000	40,000	40,000
Spain e/ 6/	600,000	600,000	600,000	600,000	600,000
Turkey	774,000	681,000	579,000	600,000 e/	600,000
United States, sold and used by producers	612,000	577,000	583,000	643,000	697,000 5/
Total	11,400,000	11,800,000	12,000,000	12,000,000 r/	12,000,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through April 27, 2001.
3/ Pumice and related materials are also produced in a number of other countries, including Japan, Mexico, and the former Soviet Union; available information is inadequate for the formulation of reliable estimates of output levels.
4/ Unspecified volcanic materials produced mainly for use in construction products (includes pumice, perlite, pozzolan, and toba).
5/ Reported figure.
6/ Includes Canary Islands.

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RARE EARTHS

By James B. Hedrick

Domestic survey data and tables were prepared by Heather A. Geissler, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Rare earths were first produced commercially in the 1880s with the mining in Sweden and Norway of the rare-earth thorium-phosphate mineral monazite. Production in Scandinavia was prompted by the invention in 1884 of the Welsbach incandescent lamp mantle, which initially required the oxides of zirconium, lanthanum, and yttrium, with later improvements requiring only the oxides of thorium and cerium. The mantles also used small amounts of neodymium and praseodymium as an indelible brand name label. The first rare-earth production in the United States was recorded in 1893 in North Carolina; however, a small tonnage of monazite was reportedly mined as early as 1887. South Carolina began production of monazite in 1903. Foreign production of monazite occurred in Brazil as early as 1887, and India began recovery of the ore in 1911. In 2000, rare-earth production was primarily from China, with lesser amounts in Brazil, India, Russia, and the United States.

The principal economic rare-earth ores are lateritic ion-adsorption clays and the minerals bastnäsite, loparite, and monazite (table 2). The rare earths are a moderately abundant group of 17 elements composed of scandium, yttrium, and the 15 lanthanides. The elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust at 60 parts per million (ppm), to thulium and lutetium, the least abundant rare-earth elements at about 0.5 ppm. In rock-forming minerals, rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates.

Scandium, whose atomic number is 21, is the lightest rare-earth element. It is the 31st most abundant element in the Earth's crust, with an average crustal abundance of 22 ppm. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium, whose atomic number is 39, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. It is represented by the chemical symbol Y and has one naturally occurring isotope. Yttrium's average concentration in the Earth's crust is 33 ppm and is the second most abundant rare earth in the Earth's crust. Yttrium is a bright silvery metal that is soft and malleable, similar in density to titanium.

The lanthanides comprise a group of 15 elements with atomic numbers 57 through 71 that include the following: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Cerium, which is more abundant than copper (whose average concentration in the Earth's crust is 50 ppm), is the most abundant member of the group at 60 ppm, followed, in decreasing order, by yttrium at 33 ppm, lanthanum at 30 ppm,

Rare Earths in the 20th Century

In 1900, rare earths were produced to supply materials for lighting applications. Cerium was recovered as a byproduct of processing the rare-earth thorium-phosphate mineral monazite for its thorium content. A small amount of cerium (1%) was added to thorium to create the mixture used to produce an incandescent lamp mantle. When heated, the oxides of thorium and cerium glowed a brilliant white and allowed homes, businesses, and factories a low-cost way to illuminate the evening hours. U.S. monazite production in 1900 was mainly from North Carolina, with a smaller amount from South Carolina, amounting to 412 metric tons valued at $48,805. Rare earths also were mined for yttrium at the start of the 20th century. The yttrium-bearing minerals gadolinite and fergusonite and lesser amounts of cyrtolite (zircon variety) were mined at Barringer Hill, TX, for use in the Nernst lamp. The incandescent lamp mantle industry was established in 1884 with mantles of zirconium, lanthanum, and yttrium oxides. By 1900, the zirconium oxide mantle mixture had been replaced with an improved, brighter oxide mixture of thorium and cerium. That same year, the Nernst lamp came into use and used rods or "glowers" made of 25% yttrium oxide and 75% zirconium oxide, essentially an yttria stabilized zirconia. In this lamp, it was necessary to heat the glowers with an auxiliary device to about 700° C, at which point it became conductive and glowed with a brilliant white incandescence caused by the ceramic's resistance. With the advent of the electric incandescent lamp around 1912, yttrium oxide's use in Nernst glowers declined. The first large-scale use of rare-earth metals occurred in 1903 with the development of iron-bearing mischmetal (a natural mixture of rare-earth metals) in a pyrophoric cerium-rich alloy (ferrocerium) for lighter flints.

In 2000, rare earths were produced in the United States by only one mine at Mountain Pass, CA. The mine produced rare-earth concentrates from the ore mineral bastnäsite. China was the world's leading producer of rare earths, producing most of its rare earths from ores of bastnäsite, monazite, and ion adsorption clays. Over the past 100 years, the use of rare earths grew from hundreds of tons in 1900 to tens of thousands of tons in 2000. The principal applications in 2000 were in automotive catalytic converters; glass polishing and ceramics; permanent magnets; petroleum refining catalysts; metallurgical additives and alloys, including rechargeable batteries; and phosphors for color monitors, televisions, and energy-efficient fluorescent lighting.

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and neodymium at 28 ppm. Thulium and lutetium, the least abundant of the lanthanides at 0.5 ppm, occur in the Earth's crust in higher concentrations than antimony, bismuth, cadmium, and thallium.

The rare earths were discovered in 1787 by Swedish Army Lieutenant Karl Axel Arrhenius when he collected the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine near the village of Ytterby, Sweden (Weeks and Leicester, 1968, p. 667). Because they have similar chemical structures, the rare-earth elements proved difficult to separate. It was not until 1794 that the first element, an impure yttrium oxide, was isolated from the mineral ytterbite by Finnish chemist Johann Gadolin (Weeks and Leicester, 1968, p. 671).

The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798° C for cerium to 1,663° C for lutetium. The unique properties of rare earths are used in a wide variety of applications.

In 2000, consumption was estimated to have increased as imports of individual rare-earth compounds increased. Production of bastnäsite continued in the United States as production of cerium concentrates resumed on a limited scale. As a result, imports of cerium compounds decreased (table 1). Since March 1998, refinery production at the Mountain Pass, CA, site of Molycorp, Inc., has been suspended because of low rare-earth prices on world markets and unresolved regulatory and permitting requirements for a wastewater system (Unocal Corp., 2000, p. 15).

Demand decreased for rare earths used in petroleum fluid cracking catalysts and in rare-earth phosphors for television, x-ray intensifying, and fluorescent and incandescent lighting. Yttrium was used primarily in lamp and cathode-ray tube phosphors, and lesser amounts were used in structural ceramics and oxygen sensors.

The domestic use of scandium increased in 2000, but overall consumption remained small. Commercial demand increased primarily as a result of increased demand for baseball and softball bats. Most scandium metal, alloys, and compounds were used in sporting goods equipment, metallurgical research, and analytical standards. Minor amounts were used in specialty lighting and semiconductors.

Production

In 2000, one mining operation in California accounted for all domestic mine production of rare earths. Molycorp, a wholly owned subsidiary of Unocal Corp., mined bastnäsite, a rare-earth fluorocarbonate mineral, by open pit methods at Mountain Pass, CA. Mine production was estimated to be 5,000 metric tons (t) of rare-earth oxide (REO) in concentrates.

Refined lanthanides were processed by two companies in 2000. Molycorp ceased production of refined compounds from bastnäsite at its separation plant at Mountain Pass in 1998. Unocal's higher environmental-related expenses in 2000 were in part related to the decontamination and decommissioning of Molycorp's Washington, PA, rare-earth metals site. Unocal also set aside $64 million for the future cost of the remediation of its operating oil and gas fields; this amount includes funds for Molycorp's Mountain Pass operation (Unocal Corp., 2001, p. 41-42).

Santuko Metal Industry Co., Ltd., of Japan was renamed Santoku Corp. in April 2000 (Santoku America, Inc., 2000, About us—Our history and our future, accessed July 18, 2001, at URL http://www.santoku.com/About%20Us.htm). Its U.S. subsidiary, Santoku America, Inc., produced rare-earth magnet and rechargeable battery alloys at its operations in Tolleson, AZ. Santoku America produced both major types of high strength permanent magnets, namely neodymium-iron-boron and samarium-cobalt. For the rechargeable battery industry, Santoku produced nickel-metal hydride (Ni-MH) alloys incorporating specialty rare-earth mischmetals. The plant also produced a full range of rare-earth metals in cast and distilled forms.

Rhodia Rare Earths Inc. announced it would change its name effective January 1, 2001, to Rhodia Electronics and Catalysis, Inc. The new name reflects Rhodia's mission to be a development partner and supplier of rare earths and advanced materials for the electronics and catalysis markets worldwide (Rhodia Rare Earths, Inc., December 18, 2000, La lettre du president, accessed July 17, 2001, at URL http://www.rhodia.ext.imaginet.fr/fr/index.htm).

Rhodia's operations produced finished rare-earth products from imported materials at its plant in Freeport, TX. Rhodia continued to operate its large-scale rare-earth separation plant in La Rochelle, France, and had additional capacity at its joint-venture Anan Kasei, Ltd. (Rhodia Rare Earths, 67%, and Santoku Metal Industry Co., Ltd., 33%) in Kobe, Japan. These plants provide Rhodia's U.S. operations with most of their supply.

Grace Davison, a division of W.R. Grace & Co., refined rare earths from rare-earth chlorides and other rare-earth compounds for petroleum fluid cracking catalysts at Chattanooga, TN. Grace Davison also produced rare-earth compounds for chemical catalysis and polishing compounds.

Essentially all purified yttrium was derived from imported compounds. The minor amounts of yttrium contained in bastnäsite from Mountain Pass, CA, are not recovered as a separate product.

Three scandium processors operated in 2000. High-purity products were available in various grades, with scandium oxide produced at up to 99.999% purity. Sausville Chemical Co. refined scandium at its facilities in Knoxville, TN. The company expected to produce high-purity scandium compounds, including oxide, fluoride, nitrate, chloride, and acetate. Boulder Scientific Co. processed scandium at its Mead, CO, operations. It refined scandium primarily from imported oxides to produce high-purity scandium compounds, including diboride, carbide, chloride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium also was purified and processed from imported oxides at Aldrich-APL in Urbana, IL, to produce high-purity scandium compounds, including oxide, fluoride, iodide, and hydrous and anhydrous chloride. The company also produced high-purity scandium metal.

Principal domestic producers of neodymium-iron-boron magnet alloys were Magnequench International, Inc., Anderson, IN; and Santuko America, Inc. (previously Rhodia, Inc.), Tolleson, AZ. Leading U.S. producers of rare-earth magnets were Crumax Magnetics, Inc., Elizabethtown, KY; Electron Energy Corp., Landisville, PA; Magnaquench UG (previously Ugimag, Inc.), Valparaiso, IN; Magnequench, Inc. (MQ), Anderson, IN; and the Magnetic Materials Division of Hitachi Metal America, Ltd., Edmore, MI, and China Grove, NC.

World production of neodymium-iron-boron magnets in 1999, for which the latest data are available, was 13,500 t for sintered magnets and 2,740 t for bonded magnets (Roskill's Letter from Japan, 2001c). Since 1990, the growth rates for magnets have been 28.6% per year for the sintered and 25.7% for the bonded. Similar growth in demand occurred over the past decade (1990-1999) for the principal rare-earth magnet component neodymium and the alloying additive dysprosium.

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In the last quarter of 1999, Moltech Corp. announced it had acquired Energizer Power Systems from Eveready Battery Co., forming the new wholly owned subsidiary Moltech Power Systems. Moltech Power Systems produced Ni-MH rechargeable batteries (Rare-earth Information Center Insight, 2000a).

MQ of Anderson, IN, announced it had purchased two companies related to its rare-earth magnet business. First, MQ purchased Ugimag's sintered samarium-cobalt and neodymium-iron-boron (Nd-Fe-B) permanent magnet operations in Singapore, Switzerland, the United Kingdom, and the United States (Valpariso, IN), from the Carbone Lorraine Group in November (Magnaquench, Inc., 2000a). In the second aquisition, MQ purchased Widia Magnet Engineering from Milacron, Inc. The new company was renamed Magnaquench GmbH. It is a wholly owned subsidiary of MQ. Located in Essen, Germany, the plant produces injection molded bonded magnets (Magnaquench, Inc., 2000b).

Demand increased for rare earths used in Ni-MH batteries. The rechargeable batteries are used in cellular phones, notebook computers, personal data assistants (PDAs), camcorders, and other portable devices. Japan, the leading producer, shipped 1.021 billion units in 2000, a 19% increase compared with 1999 (Roskill's Letter from Japan, 2001a). Ni-MH batteries were the leading rechargeable battery product, followed distantly by nickel-cadmium and lithium-ion types.

TradeTech L.L.C. announced the sale of its newsletter and rare earths and specialty metals business to High Tech Materials of Longmont, CO. The company's electronic monthly newsletter Elements is available by e-mail subscription via URL http://www.RareEarthsMarketPlace.com.

Cerac, Inc., was purchased by its chief executive officer in conjunction with the private equity group Facilitator Capital Fund.

Etrema Products, Inc., a wholly owned subsidiary of Edge Technologies, Inc., of Ames, IA, and the sole supplier of the giant magnetostrictive alloy TERFENOL-D®, signed an agreement with Westport Innovations, Inc., of Canada to supply the alloy for use in diesel engines. Westport Innovations plans to use the "smart" material to control fuel flow in natural gas fuel injectors in light-duty diesel engines. Smart materials have the ability to adapt to outside influences, such as external magnetic fields. TERFENOL-D® is an alloy of iron and the rare-earth elements terbium and dysprosium that expands or contracts with the application or removal of an external magnetic field. It is used in actuators, acoustic devices, sonar, ultrasonics, and other smart materials for the oil and gas industry (Etrema Products, Inc., 2000a).

Consumption

Statistics on domestic rare-earth consumption were developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths increased in 2000 compared with that of 1999. Domestic consumption of rare-earth metals and alloys also increased in 2000, especially for those used in permanent magnets and rechargeable batteries.

Based on information supplied by U.S. rare-earth refiners and selected consumers and an analysis of import data, the approximate distribution of rare earths by use was as follows: automotive catalytic converters, 22%; glass polishing and ceramics, 39%; permanent magnets, 16%; petroleum refining catalysts, 12%; metallurgical additives and alloys, 9%; rare-earth phosphors for lighting, televisions, computer monitors, radar, and x-ray intensifying film, 1%; and miscellaneous, 1%.

In 2000, yttrium consumption was estimated to have increased to 454 t from 428 t in 1999. Yttrium compounds and metal were imported from several sources in 2000. Yttrium was imported from China (73.8%); Japan (21.9%); the United Kingdom (2.7%); Germany (1.3%); and France (0.3%). The estimated use of yttrium, based on imports, was primarily in lamp and cathode-ray tube phosphors (92.5%), structural ceramics and abrasives (5.2%), and alloys (2.3%).

Tariffs

In 2000, U.S. tariff rates specific to the rare earths, including scandium and yttrium, were unchanged from 1999 (U.S. International Trade Commission, 2000). Selected rare-earth tariff rates for countries with normal-trade-relations and non-normal-trade-relations status, respectively, were as follows: Harmonized Tariff Schedule of the United States (HTS) code 2805.30.0000 (rare-earth metals, including scandium and yttrium, whether intermixed or interalloyed), 5.0% ad valorem and 31.3% ad valorem; HTS code 2846.10.0000 (cerium compounds), 5.5% ad valorem and 35% ad valorem; HTS code 2846.90.2010 (mixtures of rare-earth oxides except cerium oxide), free and 25% ad valorem; HTS code 2846.90.2050 (mixtures of rare-earth chlorides), free and 25% ad valorem; HTS code 2846.90.4000 (yttrium-bearing materials and compounds containing by weight greater than 19% but less than 85% yttrium oxide equivalent), free and 25% ad valorem; HTS code 2846.90.8000 [individual rare-earth compounds, including oxides, nitrates, hydroxides, and chlorides (excludes cerium compounds, mixtures of REO, and mixtures of rare-earth chlorides)], 3.7% ad valorem and 25% ad valorem; HTS code 3606.90.3000 (ferrocerium and other pyrophoric alloys), 5.9% ad valorem and 56.7% ad valorem; HTS code 7202.99.5040 [ferroalloys, other (including rare-earth silicide)], 5.0% ad valorem and 25% ad valorem; and HTS code 7601.20.9090 [aluminum alloys, other (including scandium-aluminum alloys)], free and 10.5% ad valorem.

Special rare-earth tariffs for Canada and Mexico were the result of Presidential Proclamation 6641, implementing the North American Free Trade Agreement, effective January 1, 1994. Under the agreement, tariff rates for most rare-earth products from Canada and Mexico were granted duty free status, and those that were scheduled for staged reductions have achieved duty free status. Tariff rates for most other foreign countries were negotiated under the Generalized Agreement on Tariffs and Trade Uruguay Round of Multilateral Trade Negotiations.

Stocks

All U.S. Government stocks of rare earths in the National Defense Stockpile (NDS) were shipped in 1998. Periodic assessments of the national defense material requirements may necessitate the inclusion of rare earths in the NDS at a future date.

Prices

Rare-earth prices increased in 2000. The following estimates of prices were based on trade data from various sources. All rare-earth prices remained nominal and subject to change without notice. The competitive pricing policies in effect in the industry caused most rare-earth products to be quoted on a daily

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basis. The average price of imported rare-earth chloride was $1.38 per kilogram in 2000, a decrease from $2.09 per kilogram in 1999. In 2000, imported rare-earth metal prices averaged $11.52 per kilogram, a decrease from $12.44 per kilogram in 1999. Mischmetal and specialty mischmetals comprised most rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride.) The price range of basic mischmetal was from $5.00 to $7.00 per kilogram (in metric ton quantities) at yearend 2000, unchanged from the yearend 1999 price range (Elements, 2000). The average price for imported cerium compounds, excluding cerium chloride, increased to $4.57 per kilogram in 2000 from $4.43 per kilogram in 1999. The primary cerium compound imported was cerium carbonate.

The estimated market price for bastnäsite concentrate was $5.51 per kilogram ($2.50 per pound). The price of monazite concentrate, typically sold with a minimum 55% rare-earth oxide content, including thorium oxide, free on board (f.o.b.) as quoted in U.S. dollars and based on the last U.S. import data, was unchanged at $400.00 per metric ton. In 2000, no monazite was imported into the United States. Prices for monazite remained depressed because the principal international rare-earth processors continued to process only thorium-free feed materials.

The nominal price for basic Nd-Fe-B alloy, calculated from data supplied by several U.S. producers, was $15.50 per kilogram ($7.03 per pound), f.o.b. shipping point, 2,000-pound minimum. Most alloy was sold with additions of cobalt (typically 4% to 6%) or dysprosium (no more than 4%). The cost of the additions was based on pricing before shipping and alloying fees; with the average cobalt price decreasing to $33.42 per kilogram ($15.16 per pound) in 1999, the cost would be about $0.33 per kilogram ($0.15 per pound) for each percent addition.

Rhodia quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 2000, are listed in table 3. No published prices for scandium oxide in kilogram quantities were available. Yearend 2000 nominal prices for scandium oxide were compiled from information provided by several domestic suppliers and processors. Prices decreased from those of the previous year for most grades and were listed as follows: 99% purity, $700 per kilogram; 99.9% purity, $2,000 per kilogram; 99.99% purity, $3,000 per kilogram; and 99.999% purity, $6,000 per kilogram.

Scandium metal prices for 2000 were unchanged from those of 1999 (Alfa Aesar, 1999, p. 1023-1024) and were as follows: 99.99% REO purity lump, sublimed dendritic, ampouled under argon, $175 per gram; 99.9% REO purity less-than-250-micron powder, ampouled under argon, $395 per 2 grams; 99.9% purity lump, sublimed dendritic, ampouled under argon, $267 per 2 grams; and 99.9% REO purity foil, 0.025-millimeter (mm) thick, ampouled under argon, 25 mm by 25 mm, $98.80 per item.

Scandium compound prices as listed by Aldrich Chemical Co. (2000, p. 1476-1477) were as follows: scandium acetate hydrate 99.9% purity, $61.40 per gram; scandium chloride hydrate 99.99% purity, $53.80 per gram; scandium nitrate hydrate 99.9% purity, $63.30 per gram; and scandium sulfate pentahydrate 99.9% purity, $61.00 per gram. Prices for standard solutions for calibrating analytical equipment were $23.80 per 100 milliliters of scandium atomic absorption standard solution and $360.50 per 100 mm of scandium plasma standard solution.

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of the oxide, and for higher purity distilled scandium metal have averaged about five times that cost.

Foreign Trade

U.S. exports of rare earths declined slightly and imports increased in 2000 compared with those of 1999. U.S. exports totaled 9,490,000 kilograms (kg) valued at $58.5 million, a slight decrease in quantity and an 8.5% increase in value compared with those of 1999 (table 4). Imports totaled 28,800,000 kg gross weight valued at $142 million, a 4.7% increase in quantity and a 1% decrease in value compared with those of 1999 (table 5).

In 2000, U.S. exports of rare earths were mixed with cerium compounds, which remained essentially unchanged; exports of rare-earth compounds and ferrocerium and pyrophoric alloys decreased; and exports of rare-earth metals increased. Principal destinations in 2000, in descending order, were Japan, Canada, the Republic of Korea, and Germany. The United States exported 1,370,000 kg of rare-earth metals valued at $9.6 million, a 2.6% increase in quantity compared with that of 1999. Principal destinations, in descending order of quantity, were Japan, the Republic of Korea, the United Kingdom, and Germany. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, were essentially unchanged at 3,950,000 kg valued at $18.2 million. Major destinations, in descending order of quantity, were the Republic of Korea, Germany, Taiwan, and Mexico.

Exports of inorganic and organic rare-earth compounds decreased to 1,650,000 kg in 2000 from 1,690,000 kg in 1999, and the value of the shipments increased by 19% to $23.4 million. Shipments, in descending order of quantity, were to Taiwan, the Republic of Korea, China, and Canada.

U.S. exports of ferrocerium and other pyrophoric alloys decreased to 2,530,000 kg valued at $7.39 million in 2000 from 2,660,000 kg valued at $10.7 million in 1999. Principal destinations, in descending order of quantity, were Canada, the United Arab Emirates, Hong Kong, and Japan.

In 2000, U.S. imports of compounds and alloys increased for three out of seven categories, as listed in table 5. China and France dominated the import market, especially for mixed and individual rare-earth compounds, followed by Japan and India (figure 1).

Imports of cerium compounds totaled 6,450,000 kg valued at $29.4 million. After a decrease in imports in 1999, the quantity of cerium compounds imported increased by 8%, as a result of increased demand for automotive exhaust catalysts and despite the increased production from the major domestic producer. China was the major supplier for the sixth year in a row, followed by France, Japan, and Austria.

Imports of yttrium compounds containing between 19% and 85% of weight oxide equivalent (yttrium concentrate) decreased by 64% to 97,400 kg in 2000, and the value declined by 19% to $2.59 million. China was the leading supplier of yttrium compounds, followed by Japan, France, and Germany.

Imports of individual rare-earth compounds, traditionally the major share of rare-earth imports, increased by 45% compared with those of 1999. Rare-earth compound imports increased to 15,000,000 kg valued at $71.3 million. The major sources of individual rare-earth compounds were China, France, Estonia, and Japan. Imports of mixtures of rare-earth oxides, other than cerium oxide, decreased by 63% to 2,190,000 kg valued at $9.5 million. The principal source of the mixed rare-earth oxides was

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China, with smaller quantities imported from the United Kingdom, Japan, and Germany. Imports of rare-earth metals and alloys into the United States totaled 2,060,000 kg valued at $23.7 million in 2000, a 39% increase in quantity compared with those of 1999. The principal rare-earth metal sources, in descending order of quantity, were China and Japan. Metal imports increased as demand for mischmetal for steel additives and specialty mischmetals for rechargeable batteries increased.

In 2000, imports of rare-earth chlorides decreased by 13% to 2,900,000 kg valued at $3.98 million. Supplies of rare-earth chloride, in descending order of quantity, came from China, India, the United Kingdom, and Japan. In the United States, rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts. Imports of ferrocerium and pyrophoric alloys decreased by 2.3% to 133,000 kg valued at $1.56 million. France was the principal supplier, with smaller amounts imported from Austria and Brazil.

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China, France, India, and Japan were major import sources of rare-earth chlorides, nitrates, and other concentrates and compounds (table 5). Thorium-free intermediate compounds as refinery feed were still in demand as industrial consumers expressed concerns with the potential liabilities of radioactive thorium, the costs of complying with environmental monitoring and regulations, and costs at approved waste disposal sites. In 2000, demand for rare earths increased in the United States, and imports increased by 4.6%. Consumption in China increased at a similar rate at 4.3%, while Japanese imports increased substantially by 11.6%.

In 2000, estimated world production of rare earths increased slightly to 83,300 t of REO (table 6). Production of monazite concentrate production was estimated to be 6,200 t (table 7).

World reserves of rare earths were estimated by the U.S. Geological Survey to be 100 million metric tons (Mt) of contained REO in 2000. China, with 43%, had the largest share of those world reserves. Australia's reserves include rare earths contained in monazite owing to its widespread availability as a very low-cost byproduct of heavy-mineral sands processing.

Australia.—Australia remained one of the world's major potential sources of rare-earth elements from its heavy-mineral sands and rare-earth laterite deposits. Monazite is a constituent in essentially all of Australia's heavy-mineral sands deposits. It is normally recovered and separated during processing but in most cases is either returned to tailings because of a lack of demand or stored for future sale. In 2000, major producers of heavy-mineral sand concentrates, in order of potential production, in Australia were Iluka Resources, Ltd. (formerly RGC, Ltd., and Westralian Sands, Ltd.), Tiwest Joint Venture, Consolidated Rutile, Ltd. (CRL), and Cable Sands, Ltd.

Anaconda Nickel, Ltd., entered into an agreement with Ashton Mining, Ltd., and Lynas Corp., Ltd., to acquire all outstanding shares of the Mount Weld companies from Ashton. The Mount Weld deposit is a world-class rare earth carbonatite deposit with tantalum, niobium, and titanium content. After purchasing all issued shares of the three subsidiaries, Anaconda agreed to pay A$3.2 million to Ashton on completion, to provide 50% of A$7.5 million when the deposit is developed, and to receive from Lynas A$3.2 million from the sale of Mount Weld Rare Earths Pty., Ltd. Lynas will contribute 50% of the A$7.5 million and has appointed Anaconda to complete the final feasibility studies. A royalty, limited to $A10.7 million is to be shared equally between Mount Weld Rare Earths Project and the Mount Weld Metals Project payable after all project and financing costs are paid and based on a rate of 1% per year of revenues (Anaconda Nickel, Ltd., November 21, 2000, Anaconda reaches agreement with Ashton and Mount Weld, accessed August 27, 2001, at URL http://new.anaconda.com.au/company_releases/0011/2211.pdf).

Iluka was one of the world's largest producers of heavy-mineral sands in 2000 (Iluka Resources, Ltd., 2001, p. 9). The company operated eight mines in Australia and two in the United States. Iluka's Australian subsidiary, WA Titanium Minerals, operated six mines in Western Australia, two of which opened in 2000. The company commissioned the Capel North West Mine in January near Capel. In October, WA Titanium brought online its second operation, the North Mine and Newman concentrator near Eneabba. Other mining operations were the South Mine near Eneabba and the Yoganup, the Yoganup Extended, and the Busselton mines in the southwestern region. Iluka's two east coast mines, in which it had a 43% interest, were operated by CRL on North Stradbroke Island, New South Wales.

Iluka upgraded the ore grade at its Ouyen deposit in northwestern Victoria by 28%. The inferred resource at Ouyen was increased by 1.7 Mt to 7.7 Mt grading 11.4% heavy minerals, containing 40% ilmenite, 15% rutile, and 9% zircon (Iluka Resources, Ltd., 2000, p. 3-4).

Iluka calculated resources for two of its heavy-mineral sands deposits in the Perth Basin of Western Australia. The Red Gully deposit to the north and the Dandalup deposit to the south of Perth displayed resources of 942,000 t of heavy minerals (Iluka Resources, Ltd., 2000).

Australian Zirconia, Ltd., a wholly owned subsidiary of Alkane Exploration, Ltd., announced it had produced a 99.3% zirconium oxide and hafnium oxide product from its Dubbo hard-rock rare-earth-and-zirconium-bearing deposit in New South Wales. DEMA Pty., Ltd., was the feasibility study manager and consultant for the project. The multimineral deposit is located on the Toongi alkaline intrusive that contains hafnium, lanthanides, niobium, tantalum, yttrium, and zirconium in the igneous rock trachyte. Based on a planned 200,000-metric-ton-per-year (t/yr) sulfuric acid leach process, the plant was expected to produce 3,500 t/yr zirconium oxide (and hafnium oxide), 500 t/yr to 1,500 t/yr of yttrium-lanthanide concentrate, and 900 t/yr of tantalum-niobium pentoxide concentrate (Australian Zirconia, Ltd., December 2000, Dubbo zirconia project, accessed May 8, 2001, at URL http://www.alkane.com.au/zirconia.html).

Basin Minerals, Ltd., announced the completion of a prefeasibility study of its Douglas heavy-mineral sands deposit in the Murray Basin in western Victoria. The Douglas deposit covers an area of 5,860 square kilometers and has a resource of 22.4 Mt of heavy minerals. The area contains the Acapulco, Bondi, Bondi East, and Echo strandline deposits containing 11.3 Mt of ilmenite (including leucoxene), 1.26 Mt of rutile, and 1.62 Mt of zircon. The project had an anticipated projected startup date of 2003 (Basin Minerals, [undated], Mineral sands exploration overview—Douglas project, accessed May 2, 2001, at URL http://www.basinminerals.com.au/projects.html).

Basin Minerals explored five heavy-mineral sands deposits in the Murray Basin area of South Australia, Victoria, and New South Wales. The principal deposits were the Douglas project in Victoria, the Culgoa project in northern Victoria, the Baranald-Swan Hill in New South Wales and Victoria, the Oakville in northern South Australia, and the Pooncarie in western New South Wales. Total resources of the Douglas and the Culgoa deposits were 24.4 Mt of heavy-mineral concentrates contained in 393 Mt of ore grading 6.2% heavy minerals,

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including monazite (Basin Minerals, [undated], Mineral sands exploration overview—Table 1, accessed May 2, 2001, at URL http://www.basinminerals.com.au/projects.html).

Basin Minerals acquired additional land adjacent to its Douglas deposit in Victoria. The State of Victoria awarded successful bids to Basin Minerals for block 2 in the Murray Basin which includes the former CRL WIM 100 deposit with 860 Mt of ore grading 5.9% heavy minerals (Mineral Sands Report, 2000b).

BeMaX Resouces NL announced the results of its pilot plant at its Ginkgo Mineral Sands Joint Venture (MSJV). The MSJV partners were BeMaX (50%), Imperial Mining (Aust) NL (25%), and Probo Mining Pty. Ltd. (25%). Located 120 kilometers (km) north of Mildura, Victoria, the Ginkgo deposit has an inferred resource of 260 Mt grading 2.6% heavy minerals. Initial tests showed product suitable for market including ilmenite, rutile, leucoxene, and zircon (BeMaX Resources NL, April 3, 2000, Update—Ginkgo mineral sands deposit, accessed March, 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

BeMaX purchased Imperial Mining's 25% share of MSJV, raising BeMaX's holdings to 75%. Imperial Mining was a wholly owned subsidiary of Imperial One, Ltd. (BeMaX Resources NL, October 10, 2000, Completion of purchase of Imperial Mining (Aust) NL, accessed March 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

BeMaX released information on a heavy-mineral strandline discovery that straddles BeMaX's BIP Joint Venture property and the property of Iluka Resouces in the Murray Basin. The adjacent Snapper (BeMaX) and Trelega (Iluka) deposits straddle the mining exploration claims at the southwest edge of BIP Joint Venture's EL5474 property in Victoria (BeMaX Resources NL, October 10, 2000, Mineral Sands discovery straddles boundary of BeMaX's and Iluka's Properties, accessed March 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

Mineral Deposits, Ltd. (MDL), stated that it would restart its Viney Creek dredge mine in New South Wales in 2001 because of increased demand for heavy minerals and a weak Australian dollar against the U.S. dollar. The 2,500-ton-per-hour dredge was placed on standby in April 1999 because of weak demand for rutile and zircon. The dredge will be refurbished in the last quarter of 2000. MDL's Hawks Nest dry mill continued to operate with feed from its smaller dredge operation at Fullerton, New South Wales (Mineral Sands Report, 2000c).

Tiwest Joint Venture, an Australian collaboration of U.S.-based Kerr McGee Chemical LLC's subsidiary KMCC Western Australia Pty., Ltd., and Australian-based Ticor Resources Pty., Ltd., produced heavy-mineral sands from its Cooljarloo Mine in Western Australia. In 2000, Tiwest processed 918,000 t of heavy-mineral concentrates compared with 548,498 t of heavy-mineral concentrates in 1999 (Mineral Sands Report, 2001c). The large increase in production was the result of the Cooljarloo Mine upgrade project in 2000. The capacity of heavy-mineral concentrates at Cooljarloo was increased to 675,000 t/yr from 535,000 t/yr, a 20% gain. Tiwest's expansion cost was A$20 million and was designed and implemented by contractor HBH Consultants (The Institution of Engineers, Australia, 2001, Australian Engineering Excellence Awards 2000—Cooljarloo Mine upgrade project for the Tiwest joint venture, accessed March 22, 2001, at URL http://www.ieaust.org.au/events/aeea_entrants/aeea_entrantdetails8.html).

RZM Pty., Ltd., purchased Western Metals, Ltd.'s 30% stake in the Wemen heavy-mineral sands project in the Murray Basin, Victoria, for A$5 million. Following the buyout, RZM entered into a 50-50 joint venture with the Australian company Sons of Gwalia for its Murray Basin mineral resource tenements and freehold land and a 50% share of RZM's heavy-mineral sands processing equipment and operations at Tomago, New South Wales. Production from the deposit is scheduled for 2001. Wemen is forecast to produce heavy-mineral sands over the 6 years of the mine's life (Industrial Minerals, 2000a).

Austria.—Treibacher Industrie AG announced it was being purchased for more than $100 million by August Finck Group of Munich, Germany. Treibacher AUERMET Produktionsges m.b.H, the rare-earth subsidiary of Treibacher Industrie AG, is expected to continue its planned expansion. Treibacher's capacity was 8,000 t/yr of rare-earth products and alloys and produced lighter flints, mischmetal, hydrogen storage alloys for batteries, vacuum alloys, mixed rare-earth compounds for fluid cracking catalysts, ceramic materials, additives for glass and ceramics, and specialty pure metals and alloys (Rare-earth Information Center News, 2000a).

Brazil.—Reserves of monazite contained in marine alluvial deposits were 42,000 t, and in stream placers, 40,000 t in 1999, the latest available data. The reserves of marine origin were distributed in deposits primarily in the States of Rio de Janeiro (26,730 t), Bahia (10,186 t), and Espírito Santo (4,136 t). The main placer reserves were in the States of Minas Gerais (24,396 t), Espírito Santo (11,372 t), and Bahia (3,481 t) (Fabricio da Silva, 2000, p. 107-108).

China.—Production of rare-earth concentrates in China was 70,000 t REO in 1999, the latest available data. Refined and processed products reached 60,000 t REO. Production of individual high-purity rare-earth compounds and metals was 25,000 t REO, an increase of 66% from those of 1998. Consumption within China increased by 4.3% in 1999 to about 16,000 t REO. Metallurgical applications, the major domestic use, consumed 5,200 t of equivalent REO (China Rare Earth Information, 2000a).

In 1999, China produced 160 million Ni-MH batteries containing 500 t of rare-earth metals. Rare-earth-containing steel consumed 400 t of rare earths as an alloying agent in 700,000 t of steel. Cast iron, a traditional application of rare-earth metals, consumed 3,800 t in making 1.1 Mt of metal in 1999. Nonferrous alloys, including aluminum wire and cable, used 800 t of rare earths, primarily for grain refinement and improved conduction. Consumption of rare earths by the oil industry was 3,800 t in fluid-cracking catalysts (China Online, [April 2000], China's consumption rare earth to rise 10%/yr, accessed October 11, 2000, at URL http://www.chinaonline.com/industry/metal_mining/NewsArchive/Secure/april/B200032214a.asp).

Inner Mongolian Rare Earth Group, Inc. (IMREG), was established in Baotou, Inner Mongolia, in November 1999 to address the status of the industry. Its primary goals were to integrate rare-earth research and development, production, and trade; to provide quality products; and to monitor the rare-earth industry of the region. The state-owned entity will also control the rate of rare-earth concentrate production and adjust the product structure to the market. IMREG expects to strengthen the development of the downstream processes and products and plans to improve international cooperation (China Rare Earth Information, 2000c).

Sichuan Panxi Rare Earth, Ltd., was declared bankrupt in May 2000. The company had capacity to process 2,000 t/yr of bastnäsite concentrate. Sichuan Panxi operated from May 1996 until January 1998 in Xi-xiang Village, Xichang City, in Sichuan Province (China Rare Earth Information, 2000b). The availability of rare earths from China continues to be strong,

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especially from Inner Mongolia. The rare-earth content of the iron ore mined at Baiyun Obo, Inner Mongolia, ranges from 400,000 t/yr to 500,000 t/yr REO (China Rare Earth Information, 2000d). Only a portion of this material is processed annually to recover rare earths.

Rhodia Rare Earths announced the formation of a joint venture with Beijing Founder Group Co., Ltd., and Liyang Licheng Economic General Industrial Co., Ltd., to group the holdings of the Liyang rare-earth plant and to develop new manufacturing units using Rhodia's expertise. Located in Jiangsu Province near Shanghai, the joint venture will be called Liyang Rhodia Founder Rare Earth New Material Co., Ltd. Rhodia Rare Earths will have a 45% share in the new company, which plans to develop products for the electronic, automotive, glass, and chemical markets (Rhodia Rare Earths, Inc., September 7, 2000, Rhodia develops its rare-earth activities in China, accessed July 17, 2001, at URL http://www.rhodia.ext.imaginet.fr/fr/index.htm).

France.—Rhodia of France and CTI, Inc., of the United States have signed an agreement to develop and supply rare-earth compounds used in medical imaging devices based on positron emission tomography (PET). Medical imaging with PET is based on recording the positron emissions from an intravenous tracer (Rhodia Rare Earths, Inc., June 21, 2000, Rhodia/CTI, Inc. agreement for the use of rare earths in state-of-the-art medical imaging, accessed July 18, 2001, at URL http://www.rhodia.ext.imaginet.fr/fr/index.htm). CTI manufactures whole-body 2D and 3D PET scanning devices that incorporate the rare-earth compound lutetium oxyorthosilicate (LSO) as a photon detector crystal. CTI grows LSO scintillation crystals and produces the PET detectors that incorporate the crystals (CTI, Inc., [2000], Detector systems, accessed July 19, 2001, at URL http://www.cti-pet.com/cti_detector.html).

India.—Exploration for heavy-mineral sands has increased. Australian-based MDL, and Iscor, Ltd., have formed an alliance to complete feasibility studies on three deposits in the State of Tamil Nadu at Kudiraimozhi, Sattankulam, and Navaladi (Mineral Sands Report, 2001b).

MDL and Iscor have signed a memorandum of understanding to form an alliance to develop two heavy-mineral sands deposits in Tamil Nadu State. The Tamil Nadu deposits at Kudiraimozhi and Navaladi-Sattankulam contain 1 billion metric tons of ore grading 6.2% ilmenite, 0.4% rutile, and 0.7% zircon (Mineral Deposits, Ltd., November 1, 2000, Announcements—Indian mineral sands project, accessed June 14, 2001, via URL http://www.mineraldeposits.com.au/Announcements2000.html).

Kerala Minerals and Metals, Ltd. (KMML), is planning an expansion of its operations at Chavara. KMML has reserves of 18 Mt grading up to 50% heavy minerals. The heavy minerals contain 65% to 75% ilmenite, 5% to 7% rutile, and 4% to 8% zircon (Titanium Minerals Outlook, 2000).

Japan.—Japan refined 5,625 t of rare earths in 2000 from imported ores and intermediate raw materials, an increase of 10% from that of 1999 (Roskill's Letter from Japan, 2001d). Imports of rare earths during the year were 26,928 t, an increase of 18% from those of 1999. The value of imports increased to ¥23,843 million in 2000 from ¥17,812 million in 1999. Japanese rare-earth imports of yttrium oxide, cerium oxide, lanthanum oxide, rare-earth metals, and cerium compounds (other than cerium oxide) increased. Imports of rare-earth compounds (including intermediate raw materials) and ferrocerium decreased. Imports from the United States were 530 t, a decrease from the 609 t imported in 1999.

China continued as the leading source of rare-earth imports for Japan with 22,431 t, representing 81% of the total. Imports from China in 2000 were as follows: rare-earth metals, 6,993 t; cerium compounds, 4,977 t; cerium oxide, 3,821 t; rare-earth compounds, 3,786 t; lanthanum oxide, 1,568 t; yttrium oxide, 1,181 t; rare-earth chlorides, 77 t; and ferrocerium, 28 t (Roskill's Letter from Japan, 2001b).

Kenya.—Tiomin Resources, Inc., of Toronto, Canada, raised Can$5 million through the private offering of warrants for investments in its Kwale heavy-mineral sands deposit. The money was expected to be used to acquire surface mining rights at its Kwale deposit and to finalize detailed engineering plans for the heavy-mineral sands mine (Mineral Sands Report, 2000e). The Kwale deposit is divided into three economic zones of Pliocene age: the North Dune, the Central Dune, and the South Dune. Monazite and other heavy minerals are contained in the Magarini Sands Formation. The magarini sands form a belt of low hills believed to be aeolian in origin. Resources of the Kwale deposit are 200 Mt of ore (Tiomin Resources, Inc., [undated], Kwale (rutile, ilmenite and zircon), accessed May 16, 2001, via URL http://www.tiomin.com/s/Properties.asp?PropertyInfoID=316&PropertyMapID=1034].

Based on the results of a feasibility study by LTA Process Engineering Pty., Ltd., of South Africa and Ausenco of Australia, Tiomin planned to start construction at Kwale in 2001. During its first 6 years, the mine is expected to produce 37,000 t/yr of zircon. Kwale has a mine life of 14 years (Industrial Minerals, 2000e).

Mozambique.—Kenmare Resources plc of Dublin, Ireland, bought the heavy-mineral sands dry separation plant from BHP, Ltd.'s Beenup Mine in Western Australia, which closed in 1999 after being in operation less than a year (Industrial Minerals, 2000d). The 650,000 t/yr plant was purchased for $4.7 million and was expected to be installed at the Moma Titanium Minerals Project in Mozambique (Kenmare Resources plc, 2000a).

Kenmare had previously purchased BHP's wet concentrator in January for $1.4 million (Industrial Minerals, 2000c). The acquisition of both plants from the Beenup Minsands Project is expected to save Kenmare in excess of $60 million in capital expenditures. The Moma Titanium Minerals Project is scheduled to begin production in late 2002 (Kenmare Resources plc, 2000b).

South Africa.—Iscor announced it would begin development of its Hillendale Mine in Kwazulu Natal Province in the second quarter of 2001. Full production capacity of the mine, expected to be reached in 2003, will be 550,000 t/yr ilmenite, 100,000 t/yr zircon, 40,000 t/yr rutile, and 10,000 t/yr leucoxene. Reserves at the Hillendale deposit are 73 Mt grading 5.6% valuable heavy minerals (excluding magnetite) (Iscor, Ltd., [undated], Heavy minerals—Hillendale, accessed April 22, 2001, via URL http://www.iscor.com/mainframe.asp?imgname=01). Construction of the Hillendale Mine and wet concentrator plant began in April at a cost of $137 million. Construction also began on a central mineral separation plant at Empangeni, 20 km from the mine site. The separation plant was expected to come on-stream in the third quarter (Industrial Minerals, 2000b).

Ticor, Ltd., announced in October that it began a review of Iscor's heavy-mineral sands deposits in South Africa. Ticor was interested in acquiring a 50% share of the project, which has reserves of 16 Mt of heavy minerals. The project consists of three deposits: the Hillendale, the Fairbreeze, and the Gravelotte. The Hillendale was scheduled to be the first mine developed. The mine life of the three deposits is at least 20 years (Mineral Sands Report, 2000d).

Namakwa Sands (Pty), Ltd., a wholly owned subsidiary of Anglo American plc, increased its heavy-mineral sands

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production as a result of the completion of its phase two expansion. Construction of the project, which was funded at 1.2 billion rand in 1997, was completed in 1999. Heavy-mineral sands were produced from its mine at Brand-se-Baai. Heavy-mineral concentrates were produced from its dry mill at Koekenaap (Mineral Sands Report, 2001a). The phase two expansion increased ore capacity to 12 million metric tons per year (Mt/yr) from 4 Mt/yr. The mine life of the deposit is 35 years.

Richard Bay Minerals completed construction of a new heavy-mineral sands processing plant. Completed in October 1999, the plant is designated mining plant E (Joseph, 2001).

Current Research and Technology

Rare-earth Ni-MH batteries are finding increased use in automobiles. The batteries are a powder alloy of mischmetal [nickel (Ni), cobalt (Co), manganese (Mn), and aluminum (Al)] pasted on a Ni-plated sheet. The principal alloy is produced by rapid solidification followed by a heat treatment and chemical of physical modification to increase the reactive Ni surface area. The Ni electrode is made of a spherical powder alloy of nickel-zinc-cobalt hydroxide (Ni, Zn, Co) $(OH)_2$ within a foamed Ni or Ni-fiber layer with a cobalt oxyhydroxide (CoOOH) coating. Ni-MH batteries are used in both hybrid electric vehicles (HEV) and pure electric vehicles (PEV). Commercially available HEVs in the United States in 2000 were the 1-liter, 3-cylinder-engine Honda Insight and the 1.5-liter, 4-cylinder-engine Toyota Prius. The Prius' Ni-MH battery produces 274 volts, and the Insight's outputs 144 volts. PEVs are produced internationally by Daihatsu, Honda, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, and Toyota. Driving ranges of the PEVs vary from 55 km to 240 km (Rare-earth Information Center News, 2000b).

Yttria-stabilized zirconia (YSZ), a material extensively used as an oxygen sensor in automobile engines, has been adapted for use as a sulfur dioxide (SO_2) sensor. The sensor is a layered device with a silver-coated platinum grid, a layer of silver sulfate-based salt, a YSZ ceramic layer, and a platinum electrode. To detect SO_2, the compound must first be oxidized to SO_3 on the platinum grid. In the presence of SO_3, the O_2 is dissociated on the platinum reference electrode, and the O^{2+} is conducted through the YSZ. The reaction $2Ag + O^{2+} + SO_3 = Ag_2SO_4 + 2e^-$ occurs at the sensing electrode. This electron imbalance causes a linear electromagnetic field (EMF) to occur between the reference electrode and the sensing electrode that is based on the SO_2 concentration. The concentration of SO_2 can be calculated from 1 ppm to 1,000 ppm using the Nernst equation and the linear slope of the EMF (Rare-earth Information Center Insight, 2000b).

Sixteen years after the first quasicrystalline material was discovered, researchers created the first binary quasicrystal using metallic ytterbium and cadmium. Until the development of the cadmium-ytterbium compund ($Cd_{5.7}Yb$), it was believed that three or more elements were required to form a quasicrystal. Quasicrystals have long-range atomic ordering but do not have a periodic lattice like a normal crystal. The rare-earth quasicrystal exhibits primitive icosahedral (fivefold) symmetry, and unlike previously stable quasicrystals that are peritectic, it is a congruently melting compound (Tsai and others, 2000).

A rare-earth compound was developed that may be used as a scintillation detector. The lanthanum chloride compound was doped with 10% trivalent cerium and emits at 330 and 352 nanometers. The compound cerium-doped lanthanum chloride reportedly had better energy resolution and improved response times than the thallium-doped sodium iodine, the most commonly used scintillation detector material. Scintillation detectors are used to detect x rays and gamma rays by emitting an optical photon, which is a decay product that results from being struck by the incoming radiation. Future uses are likely to be in situations that require high-energy resolution (Loef and others, 2000, p. 1467-1468).

Components for the next generation of the U.S. Navy's hybrid sonar system are being developed using rare earths by Etrema Products, Inc. Using TERFENOL-D®, an iron-terbium-dysprosium alloy, the sonar system combines traditional piezeoceramic technology to produce an improved detector system for the Navy's new class of destroyers. The new hybrid materials reportedly created smaller sonar sound sources with higher power and broader bandwidth (Etrema Products, Inc., 2000b).

A new technique for separating rare earths was created using selective reduction and fractional distillation. The process creates separation factors two orders of magnitude greater than those for solvent extraction (SX) (liquid-liquid extraction). The separation is based on the fact that rare-earth trichlorides can be selectively reduced to dichlorides by specific dihalide-reducing agents. The unreduced trichlorides are distilled off creating a two-group separation (Uda and others, 2000). Although the authors claim a large advantage in separation, others believe the technique is a batch process, while SX is a continuous process. A potential drawback of the process was high energy consumption; the new technique's reduction process requires keeping the rare earth at 700° C to 800° C for several hours, followed by vacuum distillation at about 900° C, and deposited at 600° C to 700° C (Rare-earth Information Center Insight, 2001b).

Researchers developed a new process that will allow the rare earth cerium dioxide to be used as a sunscreen. The process coats the cerium dioxide particles with a 10 nanometer layer of boron nitride which eliminated agglomeration, passivated the cerium catalytic activity, and produced a slippery feel. When incorporated into an organic thin film, the coated cerium particles had higher transparency and greater UV blocking than either titanium dioxide or zinc oxide, the commonly used sunscreen ingredients. The improved sunscreen reportedly reduced sunburn, reduced skin aging, and reduced the potential causes of skin cancer (Rare-earth Information Center Insight, 2001a).

A red-emitting rare-earth phosphor (lithium-doped $Gd_2O_3:Eu^{3+}$) was developed by researchers in Korea for color flat panel field emission displays. The phosphor reportedly had higher cathodluminescence than eithereuropium-doped yttrium oxide and europium-doped yttrium oxysulfide, the widely used commercial phosphors. The addition of lithium provided two material advances: first, it improved the sol-gel produced morphology from irregularly shaped 0.5 micron shapes to consistently sized pseudospherical particles of 2 to 3 microns; and second, it is believed to become incorporated into the crystal structure as a coactivator, transferring electron beam energy to the trivalent europium (Eu^{3+}) and creating a higher efficiency than that of Eu^{3+} by itself (Park and others, 2000).

The U.S. Department of Energy (DOE) announced the construction of the world's first hybrid fuel cell manufactured by Siemens Westinghouse Power Corp. The 220-kilowatt fuel cell and microturbine powerplant incorporate rare earths. The powerplant uses a solid oxide fuel cell (SOFC) to convert natural gas directly to electricity with nearly zero emissions. Power is produced electrochemically by passing a hydrogen-rich

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fuel over an anode and air over a cathode and separating the two by an electrolyte. In producing electricity, the only byproducts of the SOFC are heat, water, and carbon dioxide. Operating at 1,800° F, the SOFC's waste exhaust gas will power a microturbine and enhance performance by 10%. The culmination of the government-industry partnership program will be a 1-megawatt (1,000-kilowatt) fuel-cell-microturbine powerplant to be completed in late 2002 at Fort Meade, MD (U.S. Department of Energy, April 17, 2000, Department of Energy announces world's first "hybrid" fuel cell-turbine, accessed August 1, 2001, at URL http://fossil.energy.gov/techline/tl_fc_solidox_fat.html).

Research on the characterization and development of magnetic refrigeration alloys had been funded by the DOE. Scientists at the Ames Laboratory, where the materials were first developed, were rewarded with a 4-year project to study promising alloys. A team of 10 metallurgists, physicists, and chemists will explore the properties of the magnetic refrigeration group of gadolinium-silicon-germanium alloys. Ames Laboratory scientists Vitalij K. Pecharsky and Karl Gschneidner, Jr., first uncovered the energy-efficient characteristics of the alloys. A substantial advance in energy science, the use of these rare-earth alloys in automobile and home cooling and heating systems will provide substantial environmental benefits and energy savings (Ames Laboratory, 2000).

Outlook

The use of rare earths, especially in automotive pollution catalysts, permanent magnets, and rechargeable batteries, is expected to continue to increase as future demand for automobiles, electronics, computers, and portable equipment grows. Rare-earth markets are expected to require greater amounts of higher purity mixed and separated products to meet the demand. Strong demand for cerium and neodymium for use in automotive catalytic converters and permanent magnets is expected to continue throughout the decade. Future growth is forecast for rare earths in rechargeable Ni-MH batteries, fiber optics, and medical applications, including magnetic resonance imaging contrast agents, PET scintillation detectors, medical isotopes, and dental and surgical lasers. Long-term future growth is expected for rare earths in magnetic refrigeration alloys.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several world-class rare-earth deposits in Australia and China have yet to be developed because world demand is currently [2000] being satisfied by existing production (Singer, 1995). World resources should be adequate to fulfill demand for the foreseeable future.

Domestic companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has had a negative impact on monazite-containing mineral sands operations worldwide. Future long-term demand for monazite, however, is expected to increase because of its abundant supply and its recovery as a low-cost byproduct. The cost and space to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

World markets are expected to continue to be very competitive based on lower wages and fewer environmental and permitting requirements. China is expected to remain the world's principal rare-earth supplier. Economic growth in several developing countries will provide new and potentially large markets in Southeast Asia and Eastern Europe.

The long-term outlook is for an increasingly competitive and diverse group of rare-earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry is expected to continue to grow. New applications are expected to continue to be discovered and developed.

References Cited

Alfa Aesar, 1999, Alfa Aesar 1999-2000 catalog: Ward Hill, MA, Alfa Aesar, 1643 p.

Aldrich Chemical Co., 2000, Catalog handbook of fine chemicals 2000-2001: St. Louis, MO, Aldrich Chemical Co., 2061 p.

Ames Laboratory, 2000, "Cool" materials turn into hot research for Ames Laboratory: Ames, IA, Ames Laboratory news release, August 7, 1 p.

China Rare Earth Information, 2000a, China rare earth—1999: China Rare Earth Information, v. 6, no. 2, April, p. 1-2.

———2000b, Court announcement: China Rare Earth Information Center, v. 6, no. 3, June, p. 3.

———2000c, Inner Mongolian Rare Earth Group, Inc.: China Rare Earth Information, v. 6, no. 1, February, p. 1-2.

———2000d, Rare earth market—Applications and availability: China Rare Earth Information, v. 6, no. 5, October, p. 1-2.

Elements, 2000, Market prices for rare earths and specialty metals: Elements, v. 1, no. 4, December, p. 2.

Etrema Products, Inc., 2000a, Etrema Products, Inc./Edge Technologies, Inc. creates strategic supply relationship with Westport Innovations, Inc.: Ames, IA, Etrema Products, Inc., news release, November 10, 1 p.

———2000b, Next generation sonar drivers From Etrema Products: Ames, IA, Etrema Products, Inc., news release, March 22, 1 p.

Fabricio da Silva, M.B., 2000, Terras rares *in* Sumário mineral 2000: Brasília, Brazil, Departmento Nacional de Produção Mineral, p. 107-108.

Iluka Resources, Ltd., 2000, Quarterly report [1st Quarter]: Perth, Australia, Iluka Resources, Ltd., April 20, 4 p.

———2001, Annual report to shareholders 2000: Perth, Australia, Iluka Resources, Ltd., 40 p.

Industrial Minerals, 2000a, Gwalia/RZM j-v for Murray Basin: Industrial Minerals, no. 390, March, p. 13-14.

———2000b, Iscor gives go-ahead to Hillendale minsands: Industrial Minerals, no. 392, May, p. 12-15.

———2000c, Kenmare buys BHP minsands plant: Industrial Minerals, no. 389, February, p. 11-14.

———2000d, Kenmare buys second Beenup plant: Industrial Minerals, no. 393, June, p. 15-17.

———2000e, Kwale minsands feasibility update: Industrial Minerals, no. 393, June, p. 15.

Joseph, K.R., 2001, Zirconium in South Africa's mineral industry 1999/2000: Pretoria, South Africa, South Africa Department of Minerals and Energy, p. 95-97.

Kenmare Resources plc, 2000a, Kenmare buys mineral separation plant for Moma Titanium: Dublin, Ireland, Kenmare Resources plc press release, May 3, 1 p.

———2000b, Kenmare Moma project granted favorable tax status: Dublin, Ireland, Kenmare Resources plc press release, December 20, 1 p.

Loef, E.V. van, Dorenbos, D.P., van Eijk, C.W.E., Krämer, K., and Güdel, H.D., 2000, High-energy-resolution scintillators-Ce^{3+} activated $LaCl_3$: Applied Physics Letters, v. 77, no. 10, September 4, p. 1413-1516.

Magnaquench, Inc., 2000a, Magnaquench acquires Ugimag rare earth magnet business: Anderson, IN, Magnaquench, Inc., press release, November 1, 1 p.

———2000b, Magnaquench completes acquisition of Widia Magnet Engineering: Anderson, IN, Magnaquench, Inc., press release, September 29, 1 p.

Mineral Sands Report, 2000a, China—An emerging titanium industry: Mineral Sands Report, no. 61, November, p. 5-7.

———2000b, Exploration—Murray Basin tender: Mineral Sands Report, no. 61, November, p. 2.

———2000c, New sales and weak $A prompt Mineral Deposits to restart Viney Creek dredge: Mineral Sands Report, no. 61, November, p. 3.

———2000d, Ticor re-examines Iscor project: Mineral Sands Report, no. 61, November, p. 1.

———2000e, Tiomin raises $5 million: Mineral Sands Report, no. 61, November, p. 2.

———2001a, Namakwa Sands reports higher production in 2000: Mineral Sands Report, no. 66, April, p. 3.

———2001b, Potential new feedstock supply projects: Minerals Sands Report, no. 66, April, p. 4-7.

Digitized by Google

———2001c, Ranking the TiO_2 and zircon industries: Mineral Sands Report, no. 67, May, p. 4-6.
Park, J.C., Moon, H.K., Kim, D.K., Byeon, S.H., Kim, B.C., and Suh, K.S., 2000, Morphology and cathodoluminescence of Li-doped $Gd_2O_3:Eu^{3+}$—A red phosphor operating at low voltages: Applied Physics Letters, v. 77, no. 14, October 2, p. 2162-2164.
Rare-earth Information Center Insight, 2000a, Company notes: Rare-earth Information Center Insight, v. 13, no. 1, January 1, p. 2.
———2000b, SO2 sensor: Rare-earth Information Center Insight, v. 13, no. 1, January 1, p. 1.
———2001a, Rare earth sunscreen: Rare-earth Information Center Insight, v. 14, no. 2, February, p. 1.
———2001b, Separating rare earth elements: Rare-earth Information Center Insight, v. 14, no. 2, February, p. 1.
Rare-earth Information Center News, 2000a, New owner for Treibacher: Rare-earth Information Center News, v. XXXV, no. 4, p. 1.
———2000b, Nii-MH batteries put to use in new cars: Rare-earth Information Center News, v. XXXV, no. 3, p. 1, 6.
Roskill's Letter from Japan, 2001a, Batteries—Growth led by lithium ion products: Roskill's Letter from Japan, no. 294, February, p. 10-12.
———2001b, Rare earths—Japanese imports from China drop by 20%: Roskill's Letter from Japan, no. 298, June, p. 16-17.
———2001c, Rare earths—Problems and opportunities in the Chinese industry: Roskill's Letter from Japan, no. 294, February, p. 10-12.
———2001d, Rare earths—Raw material shortage: Roskill's Letter from Japan, no. 297, May, p. 13-14.
Singer, D.A., 1995, World class base and precious metal deposits—A quantitative analysis: Economic Geology, v. 90, no. 1, January-February, p. 88-104.
Titanium Minerals Outlook, 2000a, Supply—Kerala Minerals and Metals Ltd.: Titanium Minerals Outlook, February, p. 4.
Tsai, A.P., Guo, J.Q., Abe, E., Takakura, H. and Sato, T.J., 2000, Alloys—A stable binary quasicrystal: Nature, v. 408, November 30, p. 537-538.
Uda, Tetsuya, Jacob, K.T., and Hirasawa, Masahiro, 2000, Technique for enhanced rare earth separation: Science, v. 289, no. 5488, September 29, p. 2326-2329.
Unocal Corp., 2000, Form 10-K—Fiscal year 1999: Securities and Exchange Commission, 114 p.
———2001, 2000 annual report: El Segundo, CA, Unocal Corp., 127 p.
U.S. International Trade Commission, 2000, Harmonized tariff schedule of the United States: U.S. International Trade Commission Publication 3249, [unpaginated].
Weeks, M.E., and Leicester, H.M., 1968, Discovery of the elements (7th ed.): Easton, PA, Journal of Chemical Education, 896 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Rare-Earth Elements. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Rare-Earth Oxides. International Strategic Minerals Inventory Summary Report, Circular 930-N, 1993.
Rare Earths. Ch. in Mineral Commodity Summaries, annual.
Scandium. Ch. in Mineral Commodity Summaries, annual.
Thorium. Ch. in Mineral Commodity Summaries, annual.
Yttrium. Ch. in Mineral Commodity Summaries, annual.

Other

American Metal Market, daily.
China Rare Earth Information Newsletter (China).
Elements: Rare Earths, Specialty Metals and Applied Technology.
European Rare-Earth and Actinide Society (ERES) Newsletter (Switzerland).
Industrial Minerals (London), monthly.
Metal Bulletin (London), semiweekly.
Rare Earth Elements and Yttrium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Rare-earth Information Center Insight.
Rare-earth Information Center News.
The Economics of Rare Earths. Roskill Information Services Ltd. (London).

TABLE 1
SALIENT U.S. RARE EARTH STATISTICS 1/

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1996	1997	1999	1999	2000
Production of rare-earth concentrates 2/	20,400	10,000 e/	5,000 e/	5,000 e/	5,000 e/
Exports:					
Cerium compounds	6,100	5,890	4,640	3,960	4,050
Rare-earth metals, scandium, yttrium	250	991	724	1,600	1,650
Ores and concentrates	2	--	--	--	--
Rare-earth compounds, organic or inorganic	2,210	1,660	1,630	1,690 r/	1,760
Ferrocerium and pyrophoric alloys	4,410	3,830	2,460	2,360	2,300
Imports for consumption: e/					
Monazite	56	11	--	--	--
Cerium compounds	3,180	1,820	4,940	5,970 r/	6,450
Ferrocerium and pyrophoric alloys	107	121	117	120	118
Metals, alloys, oxides, other compounds	14,000	10,000	8,950	17,200	17,300
Stocks, producers and processors, yearend	NA	NA	NA	NA	NA
Consumption, apparent	NA	NA	NA	NA	NA
Prices, yearend, per kilogram:					
Bastnäsite concentrate, REO basis	$2.87	$3.53 e/ r/	$4.19 e/ r/	$4.85 e/ r/	$5.51 e/
Monazite concentrate, REO basis	$0.48	$0.73	$0.73	$0.73 e/	$0.73 e/
Mischmetal, metal basis	$8.75 3/	$8.45 3/	$16.00 3/	$16.00 3/	$16.00 3/
Employment, mine and mill	NA	NA	NA	NA	NA
Net import reliance as a percentage of apparent consumption 4/	(5/)	(5/)	(5/)	(5/)	(5/)

e/ Estimated. r/ Revised. NA Not available. -- Zero.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Comprises only the rare earths derived from bastnäsite as obtained from Molycorp, Inc.
3/ Source: Elements, TradeTech, Denver, CO.
4/ Imports minus exports plus adjustments for Government and industry stock changes.
5/ Net importer.

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TABLE 2
RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS 1/

(Percent of total rare-earth oxide)

Rare earth	Bastnasite, Mountain Pass, CA, USA 2/	Bastnasite, Bayan Obo, Inner Mongolia, China 3/	Monazite, North Capel, Western Australia 4/	Monazite, North Stradbroke Island, Queensland, Australia 5/	Monazite, Green Cove Springs, FL, USA 6/	Monazite, Nangang, Guangdong, China 7/
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Dysprosium	trace	.1000	.7000	.6000	.9000	.8000
Erbium	trace	trace	.2000	.2000	trace	.3000
Europium	.1000	.2000	.0530	.8000	.1600	.1000
Gadolinium	.2000	.7000	1.49	1.80	6.60	2.00
Holmium	trace	trace	.0530	.1000	.1100	.1200
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Lutetium	trace	trace	trace	.0100	trace	.1400
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Samarium	.8000	.8000	2.53	3.10	4.90	3.00
Terbium	trace	.1000	.0350	.3000	2600	.7000
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	.1000	.1000	.2100	2.40
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

	Monazite, east coast, Brazil 8/	Monazite, Mount Weld, Australia 9/	Xenotime, Lahat, Perak, Malaysia 2/	Xenotime, southeast Guangdong, China 10/	Rare earth laterite, Xunwu, Jiangxi Province, China 11/	Rare earth laterite, Longnan, Jiangxi Province, China 11/
Cerium	47.00	51.00	3.13	3.00	2.40	.4000
Dysprosium	.4000	.2000	8.30	9.10	trace	6.70
Erbium	.1000	.2000	6.40	5.60	trace	4.90
Europium	.1000	.4000	trace	.2000	.5000	0.10
Gadolinium	1.00	1.00	3.50	5.00	3.00	6.90
Holmium	trace	.1000	2.00	2.60	trace	1.60
Lanthanum	24.00	26.00	1.24	1.20	43.40	1.82
Lutetium	not determined	trace	1.00	1.80	.1000	.4000
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Praseodymium	4.50	4.00	.5000	.6000	9.00	.7000
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
Terbium	.1000	.1000	.9000	1.20	trace	1.30
Thulium	trace	trace	1.10	1.30	trace	.7000
Ytterbium	.0200	.1000	6.80	6.00	.3000	2.50
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

1/ Data are rounded to no more than three significant digits: may not add to totals shown.
2/ Johnson, G.W., and Sisneros, T.E., 1981, Analysis of rare-earth elements in ore concentrate samples using direct current plasma spectrometry—Proceedings of the 15th Rare Earth Research Conference, Rolla, MO, June 15-18, 1981, in The rare earths in modern science and technology: New York, Plenum Press, v. 3, p. 525-529.
3/ Zang, Zhang Bao, Lu Ke Yi, King Kue Chu, Wei Wei Cheng, and Wang Wen Cheng, 1982, Rare-earth industry in China: Hydrometallugy, v. 9, no. 2, p. 205-210.
4/ Westralian Sands Ltd., 1979, Product specifications—Effective January 1980: Capel, Australia, Westralian Sands Ltd. brochure, 8 p.
5/ Analysis from Consolidated Rutile Ltd.
6/ Analysis from RGC Minerals (USA), Green Cove Springs, FL.
7/ Xi, Zhang, 1986, The present status of Nd-Fe-B magnets in China, in The Impact of Neodymium-Iron-Boron Materials on Permanent Magnet Users and Producers Conference, Clearwater, FL, March 2-4, 1986, Proceedings: Clearwater, FL, Gotham International Inc., 5 p.
8/ Krumholz, Pavel. Brazilian practice for monazite treatment—Proceedings of the Symposium on Rare Metals, p. 78-82 (preprint)
9/ Kingsnorth, Dudley, 1992, Mount Weld—A new source of light rare earths, in TMS and Australasian Institute of Mining and Metallurgy Rare Earth Symposium, San Diego, CA, March 1-5, 1992, Proceedings: Sydney, Australia, Lynas Gold NL, 8 p.
10/ Nakamura, Shigeo, 1988, China and rare metals—Rare earth: Industrial Rare Metals, no. 94, May, p. 23-28.
11/ Introduction to Jiangxi Rare-Earths and Applied Products. Jiangxi Province Brochure at the International Fair for Rare Earths, Beijing, China, September 1985, 42 p. (in English and Chinese).

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TABLE 3
RHODIA RARE EARTH OXIDE PRICES IN 2000

Product (oxide)	Percentage purity	Standard package quantity (kilograms)	Price (dollars per kilogram)
Cerium	96.00	25	19.20
Do.	99.50	900	20.85
Dysprosium	99.00	3	120.00
Erbium	96.00	2	155.00
Europium	99.99	1	990.00 1/
Gadolinium	99.99	3	130.00
Holmium	99.90	10	440.00 2/
Lanthanum	99.99	25	23.00
Lutetium	99.99	2	3,500.00
Neodymium	95.00	20	28.50
Praseodymium	96.00	20	36.80
Samarium	99.90	25	360.00
Do.	99.99	25	435.00
Scandium	99.99	1	6,000.00
Terbium	99.99	5	535.00
Thulium	99.90	5	2,500.00
Ytterbium	99.00	10	230.00
Yttrium	99.99	50	88.00

1/ Price for quantity greater than 40 kilograms is $900.00 per kilogram.
2/ Price for quantity less than 10 kilograms is $485.00 per kilogram.

TABLE 4
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Cerium compounds: (2846.10.0000)				
Australia	8,060	$42,200	5,630	$39,000
Belgium	111,000	1,540,000	86,000	1,580,000
Brazil	51,900	486,000	205,000	337,000
Canada	96,200	684,000	201,000	1,520,000
France	135,000	807,000	124,000	515,000
Germany	828,000	1,870,000	832,000	2,460,000
Hong Kong	31,000	193,000	60,100	359,000
India	5,190	38,900	4,070	37,800
Japan	150,000	1,320,000	213,000	1,550,000
Korea, Republic of	1,230,000	5,340,000	1,150,000	4,950,000
Malaysia	320,000	1,710,000	178,000	889,000
Mexico	75,700	548,000	216,000	1,490,000
Netherlands	38,600	231,000	206,000	697,000
Singapore	24,800	85,200	15,100	83,100
South Africa	43,800	579,000	6,000	108,000
Taiwan	237,000	1,060,000	237,000	976,000
United Kingdom	480,000	1,170,000	133,000	400,000
Other	93,800	650,000	172,000	997,000
Total	3,960,000	18,400,000	4,050,000	19,000,000
Total estimated equivalent REO content.	3,960,000	18,400,000	4,050,000	19,000,000
Rare-earth compounds: (2846.90.0000)				
Austria	16,700	566,000	80,000	$2,230,000
Brazil	78,400	168,000	10,000	45,400
Canada	151,000	1,860,000	208,000	2,850,000
China	515,000	1,040,000	197,000	369,000
Colombia	18,600	44,600	13,100	3,100
Finland	73,100	2,120,000	82,000	2,720,000

See footnotes at end of table.

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TABLE 4--Continued
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Rare-earth compounds--Continued: (2846.90.0000)				
France	365	$57,900	60,900	$936,000
Germany	11,300	578,000	48,600	1,010,000
India	152,000	652,000	76,800	231,000
Japan	73,400	2,730,000	39,100	1,410,000
Korea, Republic of	150,000	974,000	204,000	1,550,000
Mexico	8,160	95,500	8,080	114,000
Taiwan	192,000	4,900,000	284,000	7,980,000
United Kingdom	20,100	1,140,000	47,900	656,000
Other	233,000	2,700,000	401,000	2,590,000
Total	1,690,000	19,600,000	1,760,000	24,700,000
Total estimated equivalent REO content.	1,690,000	19,600,000	1,760,000	24,700,000
Rare-earth metals, including scandium and yttrium: (2805.30.0000)				
China	6,450	530,000	299	74,000
France	563,000	1,120,000	125	4,510
Germany	6,710	177,000	2,270	155,000
Japan	657,000	1,720,000	1,180,000	3,110,000
Korea, Republic of	9,450	276,000	19,700	192,000
Taiwan	2,160	39,400	996	18,600
United Kingdom	2,170	212,000	15,000	250,000
Other	89,400	1,200,000	149,000	6,030,000
Total	1,340,000	5,280,000	1,370,000	9,830,000
Total estimated equivalent REO content.	1,600,000	5,280,000 r/	1,650,000	9,830,000
Ferrocerium and other pyrophoric alloys: (3606.90.0000)				
Argentina	42,100	72,900	26,600	61,500
Australia	3,260	24,300	3,600	107,000
Brazil	21,200	76,100	436	11,000
Canada	1,060,000	1,810,000	1,020,000	2,100,000
Chile	13,900	27,700	25,100	31,300
Colombia	3,020	11,700	1,000	3,510
Costa Rica	--	--	831	3,000
France	4,310	164,000	3,580	153,000
Germany	19,400	63,500	55,100	155,000
Greece	28,600	121,000	30,700	73,600
Hong Kong	172,000	449,000	240,000	547,000
Ireland	--	--	227	3,900
Italy	998	$128,000	3,340	$82,300
Japan	175,000	1,570,000	213,000	1,230,000
Korea, Republic of	10,100	7,380	1,890	41,700
Kuwait	37,800	51,500	38,200	74,900
Mexico	27,300	401,000	85,500	699,000
Netherlands	87,500	511,000	83,100	270,000
New Zealand	24,900	53,900	12,900	36,900
Saudi Arabia	136,000	2,910,000	225	5,890
Singapore	41,200	133,000	37,100	112,000
South Africa	16,100	28,300	1,550	137,000
Spain	457	11,000	12	8,320
Taiwan	132,000	221,000	40,300	77,000
United Arab Emirates	283,000	431,000	262,000	316,000
United Kingdom	37,000	225,000	39,400	177,000
Other	285,000	1,190,000	365,000	1,090,000
Total	2,660,000	10,700,000	2,590,000	7,620,000
Total estimated equivalent REO content.	2,360,000	10,700,000 r/	2,300,000	7,620,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ U.S. International Trade Commission Harmonized Tariff Schedule of the United States category number.

Source: U.S. Census Bureau.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates: (2846.10.0000)				
Austria	36,700	$396,000	49,600	$468,000
China	3,570,000	13,400,000	3,470,000	13,500,000
France	2,160,000	7,640,000	2,390,000	7,130,000
Japan	188,000	4,360,000	410,000	7,820,000
Other	22,000	373,000	134,000	561,000
Total	5,970,000	26,200,000	6,450,000	29,400,000
Total estimated equivalent REO content	3,990,000	26,200,000 r/	4,310,000	29,400,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent: (2846.90.4000)				
China	231,000	2,640,000	47,600	847,000
France	36,000	505,000	16,000	260,000
Germany	--	--	8,000	250,000
Japan	612	50,800	18,600	1,080,000
United Kingdom	1	4,010	623	8,410
Other	--	--	6,640	144,000
Total	268,000	3,200,000	97,400	2,590,000
Total estimated equivalent REO content	161,000	3,200,000 r/	58,400	2,590,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides: (2846.90.8000)				
Austria	27,500	928,000	23,600	732,000
China	7,000,000	19,500,000	7,840,000	21,400,000
Estonia	16,000	21,900	560,000	335,000
France	2,720,000	13,800,000	6,090,000	16,400,000
Germany	1,100	242,000	9,700	855,000
Hong Kong	1,000	10,700	524	34,200
Japan	468,000	10,900,000	327,000	10,700,000
Malaysia	5,040	569,000	--	--
Norway	35,600	$18,500,000	22,000	$12,800,000
Russia	101	90,600	2,430	42,200
Taiwan	19,000	152,000	--	--
United Kingdom	53,300	6,720,000	84,300	7,820,000
Other	1,220	136,000	3,810	205,000
Total	10,300,000	71,600,000	15,000,000	71,300,000
Total estimated equivalent REO content	7,760,000	71,600,000 r/	11,200,000	71,300,000
Mixtures of rare-earth oxides except cerium oxide: (2846.90.2010)				
Austria	29,400	1,800,000	6,950	348,000
China	5,910,000	9,690,000	2,120,000	5,070,000
France	1,920	31,400	445	14,500
Germany	4,350	280,000	7,570	191,000
Japan	21,300	3,610,000	24,300	3,450,000
Russia	21	6,480	75	33,700
United Kingdom	3,540	73,800	25,100	376,000
Other	1,230	46,400	6,210	54,500
Total	5,980,000	15,500,000	2,190,000	9,530,000
Total estimated equivalent REO content	5,980,000	15,500,000	2,190,000	9,530,000
Rare-earth metals, whether intermixed or alloyed: (2805.30.0000)				
China	963,000	9,090,000	1,420,000	13,600,000
Hong Kong	30,100	541,000	33,600	526,000
Japan	439,000	7,840,000	555,000	8,480,000
Russia	872	203,000	10	7,000
United Kingdom	26,800	442,000	42,100	982,000
Other	25,500	357,000	3,240	139,000
Total	1,480,000	18,500,000	2,060,000	23,700,000
Total estimated equivalent REO content	1,780,000 r/	18,500,000 r/	2,470,000	23,700,000
Mixtures of rare-earth chlorides, except cerium chloride: (2846.90.2050)				
China	3,150,000	3,950,000	1,800,000	1,820,000
France	114	5,980	17,200	332,000
India	81,900	106,000	913,000	756,000
Japan	79,700	2,730,000	21,800	660,000
United Kingdom	12,100	65,000	56,100	221,000

See footnotes at end of table.

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TABLE 5 --Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Mixtures of rare-earth chlorides, except cerium chloride--Continued: (2846.90.2050)				
Other	3,410	$94,000	83,600	$192,000
Total	3,330,000	6,960,000	2,900,000	3,980,000
Total estimated equivalent REO content	1,530,000	6,960,000 r/	1,330,000	3,980,000
Ferrocerium and other pyrophoric alloys: (3606.90.3000)				
Austria	9,020	207,000	15,300	262,000
Brazil	3,000	56,100	3,000	56,500
France	120,000	1,580,000	107,000	1,130,000
Other	3,780	78,100	7,630	112,000
Total	136,000	1,920,000	133,000	1,560,000
Total estimated equivalent REO content	120,000	1,920,000 r/	118,000	1,560,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ U.S. and International trade commission of harmonized code tariff category number.

Source: U.S. Census Bureau.

TABLE 6
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of rare earth oxide equivalent)

Country 3/	1996	1997	1998	1999	2000 e/
China e/	55,000	53,000	60,000	70,000	73,000
India e/	2,700	2,700	2,700	2,700	2,700
Malaysia	340	418	350 e/	625	450
Sri Lanka e/	120	120	120	120	120
Thailand	--	12	-- e/	--	--
U.S.S.R. e/ 4/	2,000	2,000	2,000	2,000	2,000
United States e/ 5/	20,400 6/	10,000	5,000	5,000	5,000
Total	80,600	68,300	70,200	80,400	83,300

e/ Estimated. -- Zero.
1/ World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through May 27, 2001.
3/ In addition to the countries listed, rare-earth minerals are believed to be produced in Indonesia, Mozambique, North Korea, and Vietnam, but information is inadequate for formulation of reliable estimates of output levels.
4/ Dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual producing countries, including Kazakhstan, Krygystan, Russia, and Ukraine.
5/ Comprises only the rare earths derived from bastnäsite as reported from company sources.
6/ Reported figure.

TABLE 7
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1996	1997	1998	1999	2000 e/
Brazil e/	-- r/	460 r/	-- r/	-- r/	--
India e/	5,000	5,000	5,000	5,000	5,000
Malaysia	618	767	517 r/	1,147 r/	1,000
Sri Lanka e/	200	200	200	200	200
Thailand	--	12	--	--	--
Total	5,820 r/	6,440 r/	5,720 r/	6,350 r/	6,200

e/ Estimated. r/ Revised. -- Zero.
1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through April 18, 2001.
3/ In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and countries of the former Soviet Union may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.

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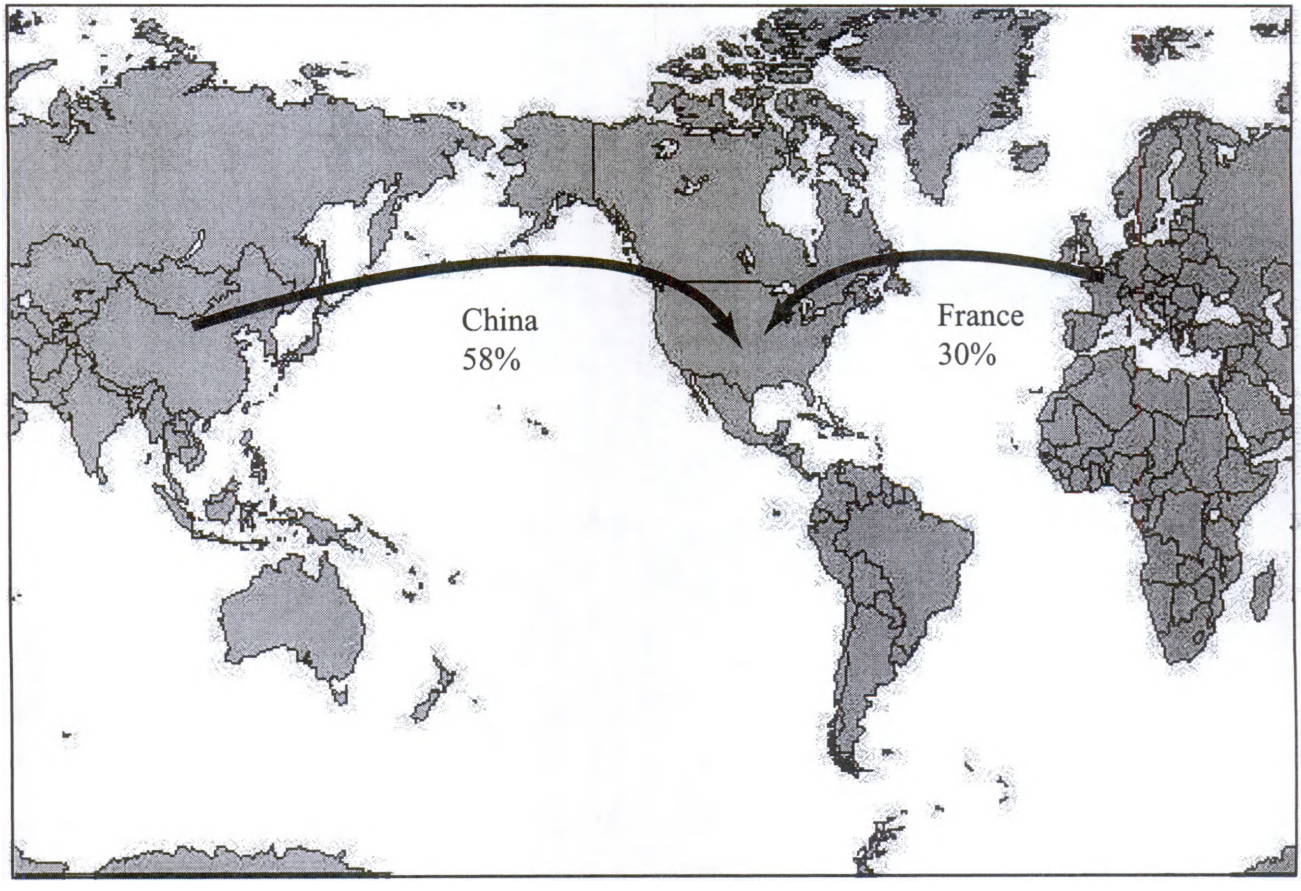
FIGURE 1
PRINCIPAL SOURCES OF U.S. IMPORTS OF RARE EARTHS IN 2000

(Percentage by weight)



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RECYCLING—METALS

By Staff

Introduction[1]

Metals are important, reusable resources. Although the ultimate supply of metal is fixed by nature, human ingenuity plays a role in determining quantity of supply available for use at any point in time by developing economic processes for the recovery of primary metal (i.e., from the Earth) and secondary metal (i.e., from the use process stream). The reusable nature of metals contributes to the sustainability of their use.

Recycling, a significant factor in the supply of many of the metals used in our society, provides environmental benefits in terms of energy savings, reduced volumes of waste, and reduced emissions associated with energy savings. Table 1 shows salient U.S. apparent supply and recycling statistics for selected metals. Apparent metal supply of 152 million metric tons (Mt) was valued at $44.0 billion in 2000. By weight, iron and steel accounted for 88.0% of apparent supply. By value, aluminum accounted for 36.0% of apparent supply and iron and steel accounted for 29.2%. Recycling contributed 80.7 Mt of metal, valued at about $18.2 billion, or over one-half of metal apparent supply by weight.

This report summarizes metal recycling. The U.S. Geological Survey publishes separate annual reviews for each of the metals summarized in this report; those reviews contain more detailed information about individual metals and recycling of those metals.

Primary indicates material from ore deposits; secondary, from recycled materials, including used products and residual materials from manufacturing. Recycling practices, and the description of those practices, vary substantially among the metal industries covered in this report. Generally, scrap is categorized as new or old, where new indicates preconsumer sources and old suggests postconsumer sources. The many stages of industrial processing that precede an end product are the sources of new scrap. For example, when metal is converted into shapes—plates, sheets, bars, rods, etc.—new scrap is generated in the form of cuttings, trimmings, and off-specification materials. When these shapes are converted to parts, new scrap is generated in the form of turnings, stampings, cuttings, and off-specification materials. Similarly, when parts are assembled into products, new scrap is generated. Once a product completes its useful product life, it becomes old scrap. Used beverage cans and junked automobiles are examples of old consumer scrap; used jet engine blades and vanes are an example of old industrial scrap. A wide variety of descriptive terms including home scrap, mill scrap, purchased scrap, prompt scrap, etc. have evolved to describe scrap generated by a wide variety of industry practices.

Aluminum[2]

Various forms of aluminum scrap are recovered by almost every segment of the domestic aluminum industry. Integrated primary aluminum companies, independent secondary smelters, fabricators, foundries, and chemical producers are known to recover aluminum from scrap. Integrated primary aluminum companies and independent secondary smelters, however, are the major consumers of scrap.

The independent secondary aluminum smelters consume scrap and produce alloys for the diecasting industry. A cursory look at the distribution of these smelters in the United States reveals a heavy concentration of smelters in the automotive and appliance manufacturing areas of the country.

The other major consumers of aluminum scrap are the integrated aluminum companies. The integrated companies frequently purchase scrap from their industrial customers directly or on a contract-conversion basis. Major integrated aluminum companies also operate can recycling programs and have established thousands of collection centers around the country for used aluminum beverage cans.

Used beverage can (UBC) scrap is the major component of processed old aluminum scrap, accounting for approximately one-half of the old scrap consumed in the United States. Most UBC scrap is recovered as aluminum sheet and manufactured into aluminum beverage cans. Most of the other types of old scrap are recovered in the form of alloys used by the diecasting industry; the bulk of these die casts is used by the automotive industry.

Aluminum recovered from purchased scrap decreased by 7% in 2000 compared with that of 1999. Of the 3.45 Mt of recovered metal, 60% came from new (manufacturing) scrap, and 40%, from old (discarded aluminum products) scrap.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries, Inc., 62.6 billion aluminum UBCs were recycled in the United States in 2000, for a beverage can recycling rate of 62.1% or nearly 2 of every 3 aluminum cans shipped. Although the recycling rate was slightly lower than the 1999 rate of 62.5%, this was the 12th consecutive year that the U.S. recycling rate exceeded 60%. According to the organizations, the average aluminum beverage can produced domestically is comprised of more than 51% recycled content (Aluminum Association Inc., 2001).

Purchase prices for aluminum scrap, as quoted by American Metal Market, fluctuated during the year but closed at lower levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 47.5 to 48.5 cents per pound; old sheet and cast aluminum, 38.5 to 39.5 cents per pound; and clean, dry aluminum turnings, 40 to 41 cents per pound.

Aluminum producers' buying price range for processed and delivered UBCs, as quoted by American Metal Market, also closed lower at yearend. The price range began the year at 57 to 59 cents per pound and closed the year at 53 to 54 cents per pound. Resource Recycling published a monthly transaction

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price for aluminum UBCs in its Container Recycling Report. During the year, the monthly average decreased significantly from 62.9 cents per pound in January to 53.9 cents per pound in December. However, the annual average price for aluminum UBCs in 2000 of 57.7 cents per pound was higher than the 1999 annual average of 50.6 cents per pound.

The yearend indicator prices for selected secondary aluminum ingots, as published in American Metal Market, also decreased significantly compared with those of 1999. The closing prices for 2000 were as follows: alloy 380 (1% zinc content), 68.7 cents per pound; alloy 360 (0.6% copper content), 74.1 cents per pound; alloy 413 (0.6% copper content), 73.8 cents per pound; and alloy 319, 72.7 cents per pound. Platt's Metals Week published an annual average U.S. price of 65.6 cents per pound for A-380 alloy (3% zinc content). The average annual London Metal Exchange (LME) cash price for a similar 380 alloy was 55.2 cents per pound.

Beryllium[3]

Beryllium is used in many applications where such properties as light weight and stiffness are important. In 2000, the United States, one of only three countries that processed beryllium ores and concentrates into beryllium products, supplied most of the rest of the world with these products.

Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications and account for the largest share of annual U.S. apparent consumption on a beryllium-metal-equivalent basis. Beryllium metal is used principally in aerospace and defense applications, and beryllium oxide serves mainly as a substrate for high-density electronic circuits. Because of its high cost, beryllium use is restricted to those applications in which its properties are crucial. Such substitutes as graphite composites, phosphor bronze, steel, and titanium are available for certain beryllium applications but with a substantial loss in performance.

In 2000, U.S. apparent consumption of beryllium totaled about 300 metric tons. Unknown quantities of new scrap generated in the processing of beryllium metal and beryllium-copper alloys were recycled. The new scrap generated during the machining and fabrication of beryllium metal and alloys was returned to the metal-alloy producers for recycling. The beryllium in beryllium-copper fabricated parts was so widely dispersed in products, and so highly diluted when those products were recycled, that it was essentially dissipated. Additionally, small quantities of obsolete military equipment containing beryllium were recycled (Cunningham, 2001a; Petkof, 1985).

Cadmium[4]

The amounts of secondary or recycled cadmium are difficult to estimate for several reasons. In the recycling of baghouse dusts from lead and copper smelters, for example, the recovered cadmium subsequently enters primary cadmium production circuits at zinc refining operations and is included in the production statistics for primary cadmium metal. There are no firm figures on the amounts of cadmium recovered from sources such as electroplating waste, filter cakes, sludges, and other cadmium-containing wastes. The total amount of secondary cadmium, estimated by the International Cadmium Association, was about 10% of 2000 world primary production.

Recycling of cadmium is a young but growing industry spurred by environmental concerns and regulatory moves to limit dissipation of cadmium from discarded cadmium products. Because about three-fourths of cadmium is used in nickel-cadmium (NiCd) batteries, and because batteries are easy to recycle, most of the secondary cadmium comes from spent NiCd batteries. Another form of old scrap that is easy to recycle is the flue dust generated during recycling of galvanized steel scrap in electric arc furnaces. Most of the new scrap for recycling is generated during manufacturing processes, such as die casting. All other applications use materials that are low in cadmium concentration and, therefore, are difficult to recycle for cadmium. Consequently, much of this cadmium is dissipated.

In 2000, the annual rate of secondary production in the United States amounted to about 200 metric tons (t). The International Metals Reclamation Co. Inc. (Inmetco) in Ellwood City, PA, is the only cadmium recycling company in the United States. Although the plant was established in 1978, cadmium recovery did not begin until 1996. Large batteries, usually weighing more than 2 kilograms (kg) and containing an average of 15% cadmium, are emptied of their electrolyte and dismantled. Detached cadmium plates then go directly into the furnace, using the high temperature metal recovery process (HTMR). Cadmium in smaller sealed batteries is recovered by burning off the castings and separators at a lower temperature than used in the HTMR process. The resulting 99.95% pure cadmium is shipped to battery manufacturers for reuse.

The future of cadmium recycling, and of cadmium industry in general, could be profoundly affected by a proposed ban of cadmium use in Europe by the European Commission. According to the European Union's Directive 2000/60/EC on water, the ban on Ni-Cd batteries is to start in 2008, if approved by the European Parliament.

Chromium[5]

The major end use of chromium is in stainless steel, and this is the major form in which chromium is recycled. Chromite ore is smelted to make ferrochromium, a chromium-iron alloy that results from the removal of oxygen from chromite. Ferrochromium is then added to iron at steel-producing plants to make the iron-chromium alloy that is commonly called stainless steel. Stainless steel scrap can substitute for ferrochromium as a source of chromium. Stainless steel is composed of two broad categories—austenitic and ferritic. The names are related to the molecular structure of the steel but also identify which grades require nickel (austenitic) and which do not (ferritic). Nickel content increases the price of the alloy and its resulting scrap.

Scrap is generated during the manufacturing process (new scrap) and as a result of recycling obsolete equipment (old scrap). Scrap from these sources is collected and sorted by grade (i.e., chemical composition) in scrap yards. Scrap brokers

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play a role in moving material from where it is recovered to where it is consumed. The steel industry consumes stainless steel scrap as a source of chromium and nickel. Thus chromium units are recycled when stainless steel is reused. A study of domestic stainless steel found that its average chromium content is about 17% (Papp, 1991, p. 1).

Cobalt[6]

Cobalt-bearing scrap is generated during manufacture and/or following use in these applications—catalysts used by the petroleum and chemical industries; cemented carbides used in cutting and wear-resistant applications; rechargeable batteries; and superalloys, magnetic and wear-resistant alloys, and tool steels. Depending on the type and quality of the scrap, it might be recycled within the industry sector that generated it, processed to reclaim the cobalt as a cobalt chemical or metal powder, downgraded by using it as a substitute for nickel or iron in an alloy with a lower cobalt content, or processed to an intermediate form that would then either be further refined or downgraded. The products of recycled cobalt scrap include alloys; mixed metal residues; pure cobalt metal, metal powder, or chemicals; and tungsten carbide-cobalt powders.

In 2000, scrap consumption reported by U.S. cobalt processors and consumers was 2,550 t of contained cobalt, a decrease of 6% from the 2,720 t consumed in 1999. U.S. imports of cobalt waste and scrap increased by 41% to 550 t, gross weight, valued at $4.1 million. Seven countries supplied more than 90% of these materials—the United Kingdom (43%), France (13%), Germany (11%), Canada (10%), Japan (6%), and Argentina and Belgium (5% each). U.S. exports of cobalt waste and scrap are reported in combination with exports of unwrought cobalt metal and metal powders.

Copper[7]

According to data compiled by the International Copper Study Group (International Copper Study Group, 2001, p. 16), estimated world production of secondary refined copper increased by about 3% in 2000 to 2.1 Mt and accounted for 14.2% of global world refined copper production. According to data compiled by the World Bureau of Metal Statistics (World Bureau of Metal Statistics, 2001, p. 42) and adjusted by the U.S. Geological Survey, an additional 3.13 Mt of copper was recovered from the direct remelting of copper scrap, a decline of about 60,000 t from that of 1999 revised data. Secondary refined production in the United States continued its downward trend, declining by more than 20,000 t (9%) in 2000, based on revised data. Secondary refined production has fallen by about 190,000 t (47%) since 1997 owing to contraction of the secondary smelting/refining industry. Copper recovered in alloys and chemicals (direct melt scrap) was essentially unchanged at 1.10 Mt.

Copper scrap prices generally followed the trend in refined copper prices, though the discount for various grades of scrap tended to narrow with lower prices. Despite growing global inventories, copper prices in January continued the upward trend begun in mid-1999, and rose to their highest level in almost 2 years. The COMEX spot price averaged $0.85 per pound in January. However, prices weakened beginning in March, the COMEX price averaging only $0.80 in the March to June period. In response to declining global inventories, the average monthly COMEX price climbed to $0.91 in September. Prices weakened and fluctuated during the fourth quarter of the year, the COMEX price averaging $0.86 and finishing the year at $0.85. The average annual COMEX price of $0.84 was at its highest level since 1997. While the discount to COMEX prices for No. 1 (brass mill) scrap and No. 2 (refiners) scrap averaged 3.3 cents per pound and 19.0 cents per pound, respectively, for the year, margins narrowed to below 3 cents and 17.5 cents per pound during the period of low copper prices at midyear and rose to 4.6 cents and 19 cents, respectively, during December.

According to data compiled by the International Copper Study Group (2001, p. 40-43), global trade in copper scrap increased significantly in 2000, principally owing to increased shipments from the United States, which rose from 315,000 t (estimated copper content 258,000 t) to 485,000 t (estimated copper content 395,000 t). The United States was the largest international source for copper scrap, accounting for about 17% of all reported scrap exports. China (including Hong Kong), which reported copper scrap receipts of 2.6 Mt, up from 1.8 Mt in 1999, was the largest recipient of scrap, accounting for about 54% of reported global scrap imports. It was also the largest recipient of U.S. scrap, accounting for 46% of all scrap exports. Data on world scrap trade are incomplete, however, with reported imports generally exceeding reported exports. In the case of China, it is believed that import data may include some very low-grade or misclassified material. In 2000, U.S. imports of copper scrap of 112,000 t were essentially unchanged. Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap, accounting for 79% of imports in 2000.

During 2000, two secondary smelters and three fire refineries processed scrap to recover unalloyed copper products in the United States. Scrap was also consumed in relatively small quantities at several of the primary smelters. One fire refinery in Missouri, Warrenton Refining Co., which had closed in 1999, reopened under new ownership.

In May, Southwire Co. closed its secondary smelter and associated electrolytic refinery, in Carrollton, GA. Southwire continued to operate its rod mill housed within its Copper Division Southwire (CDS). Sixteen months prior, as part of a restructuring plan aimed at lowering its costs, Southwire had unsuccessfully placed its Carrollton copper smelter/refinery operations on the market. Southwire cited economic factors, including the continued cost of compliance with environmental regulations in the metro-Atlanta area, for the closure of copper smelting operations. CDS was constructed in 1972, at a time when primary producers exerted greater control over copper prices. As part of the closure justification, Southwire cited the advent of worldwide commodity prices and their own "strong buying position" as leverage in meeting future raw material needs (Southwire Co., 2000). Southwire processed a mixture of imported blister and copper scrap at its smelter to produce anode for electrolytic refining. Southwire, which had a capacity to produce 140,000 tons per year (t/yr), of refined copper, was one of two remaining secondary smelters in the United States, two other smelters having closed in the preceding 3 years.

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Southwire closed its other secondary copper smelter in Gaston, SC, at the end of 1994, also citing the high cost of environmental compliance as the reason for closure.

Direct melt scrap, principally alloy scrap, was consumed at about 35 brass mills, 20 alloy ingot makers, and 500 foundries, chemical plants, and miscellaneous consumers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-base scrap, copper smelters and refiners recovered 16%; brass mills, 64%; brass and bronze ingot makers, 9%; and miscellaneous manufacturers (including aluminum and steel alloy producers), foundries, and chemical plants, 11%. Alloyed copper products accounted for about 83% of the total copper recovered from scrap.

In 2000, copper recovered from all refined or remelted scrap (about 28% from old scrap and 72% from new scrap) composed 32% of the total U.S. copper supply and had an equivalent refined value of $2.6 billion. Despite a slight decline in copper recovery from scrap, the equivalent refined value of copper recovered from scrap rose by about 15% in 2000 owing to higher average copper prices. Copper recovered from old scrap continued its 3-year decline, falling 5% to 363,000 t and was down by 27% from that recovered in 1997. Copper recovered from new scrap increased nominally to 952,000 t, reflecting an overall increase in brass mill shipments to the domestic market.

Gallium[8]

Because of the low yield in processing gallium to optoelectronic devices or integrated circuits, substantial quantities of new scrap are generated during the various processing stages. These wastes have varying gallium and impurity contents, depending upon the processing step from which they result. Gallium arsenide (GaAs)-based scrap, rather than metallic gallium, represents the bulk of the scrap that is recycled. During the processing of gallium metal to a GaAs device, waste is generated in several stages. If the ingot formed does not exhibit single crystal structure or if it contains excessive quantities of impurities, the ingot is considered to be scrap. Also, there is some GaAs that remains in the reactor after the ingot is produced, which may be recycled. During the wafer preparation and polishing stages, significant quantities of wastes are generated. Before wafers are sliced from the ingot, both ends of the ingot are cut off and discarded, because impurities are concentrated at the tail end of the ingot, and crystal imperfections occur at the seed end. These ends represent up to 25% of the weight of the ingot. As the crystal is sliced into wafers, two types of wastes are generated—saw kerf, which is essentially GaAs sawdust, and broken wafers. When the wafers are polished with an abrasive lapping compound, a low-grade waste is generated. During the epitaxial growth process, various wastes are produced, depending on the growth method used. Because GaAs is a brittle material, wafers may break during the fabrication of electrical circuitry on their surfaces. These broken wafers also may be recycled. Gallium content of these waste materials varies from less than 1% to as much as 99.99%. In addition to metallic impurities, the scrap may be contaminated with other materials introduced during processing such as water, silicone oils, waxes, plastics, and glass (Kramer, 1998, p. 15).

In processing GaAs scrap, the material is crushed, if necessary, then dissolved in a hot acidic solution. This acid solution is neutralized with a caustic solution to precipitate the gallium as gallium hydroxide, which is filtered from the solution and washed. The gallium hydroxide filter cake is redissolved in a caustic solution and electrolyzed to recover 99.9% to 99.99% gallium metal (Kramer, 1998, p. 15).

Some GaAs manufacturers may recycle their own scrap, or scrap may be sold to metal traders, to a company that specializes in recycling GaAs, or to the GaAs manufacturer's gallium supplier, who can recover the gallium and return it to the customer. Generally the prices commanded by GaAs scrap parallel the price fluctuations of 99.99%-pure gallium metal. Also, prices are dependent on the type and gallium content of the scrap. GaAs scrap that is recycled is new scrap, which means that it has not reached the consumer as an end product, and it is present only in the closed-loop operations between the companies that recover gallium from GaAs scrap and the wafer and device manufacturers (Kramer, 1998, p. 15).

Gold[9]

Old scrap consists of gold-containing products that have been discarded after use, and generally contributes 13% to 25% of the total U.S. supply of gold. New scrap is generated during manufacturing processes and, for the most part, remains the property of the manufacturers; it is not counted as part of the market supply. The scrap component of the gold supply is perhaps the most difficult of all metal supply components to quantify. In many areas of the world, especially in those areas where the holding of gold is encouraged by tradition, secondary gold, especially that derived from gold jewelry, changes hands both locally and internationally, often using goldsmiths as collection sites. This flow is often in response to variations in the gold price and usually cannot be followed statistically.

A considerable quantity of scrap is generated during manufacturing, but because of tight controls over waste materials in precious metals plants, nearly all of this "home-generated" scrap can be recovered. Probably the greatest loss in gold fabrication takes place in gold-plating plants where fouled or depleted solutions are sometimes discarded. Some old scrap, however, is lost because, in practice, gold cannot be economically recovered from all manufactured products.

Gold-bearing scrap is purchased on the basis of gold content, as determined by analytical testing and the market price for gold on the day that the refined product is available for sale. Processing charges and adjustments for processing losses are deducted from the total value in settling payments. Aside from dealer-processors and refiners, scrap gold has no market. The Federal Trade Commission requirement for karat identification of jewelry alloys requires gold refiners to identify the chemical analysis of the alloys they purchase and to separate the constituents of scrap to assure meeting karat standards [Public Law 226, An act forbidding the importation, exportation, or carriage in interstate commerce of falsely or spuriously stamped articles of merchandise made of gold or silver or their alloys, and for other purposes, 1906, 59th Congress, 1st Session,

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Revised Statute U.S. v. 34, part 1, June 13, p. 260].

Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from manufacturing operations, and the remainder comes from old scrap in the form of such items as discarded jewelry and dental materials, used plating solutions, and junked electronic equipment. A few dozen companies, out of several thousand companies and artisans, dominate the fabrication of gold into commercial products. Most of the domestic scrap is processed by refiners centered in New York, NY, and Providence, RI; refiners are also concentrated in areas of California, Florida, and Texas, although the current trend seems to be toward a less centralized industry. Scrap dealers may process the scrap and then ship the upgraded product to refiners and fabricators for further treatment and refining. The U.S. Department of Defense (DOD) recovers significant quantities of gold from military scrap (Laura Green, Precious Metals Specialist, Defense Logistics Agency, oral commun., 1998). Other Federal Government agencies either participate in the DOD recovery program or have one of their own. DOD awarded contracts to manage more than 11 million kilograms of electronic scrap anticipated to be collected through the middle of 2000 (American Metal Market, 2000a).

Domestic consumption of new and old gold scrap was 42,000 kg and 70,000 kg respectively. These data were collected in 2000 by the U.S. Geological Survey, and include 30,000 kg of old imported scrap. In 2000, U.S. exports of gold scrap increased, after 2 years of decrease, while imports stayed at their highest level since 1995. As it has been for many years, the United States was a net exporter of gold scrap in 2000.

Prices for gold waste and scrap imported and exported in 2000 averaged $74 and $226 per troy ounce, respectively; at the same time, the average price for gold was $280 per ounce (Platts Metals Week, 2001).

Indium[10]

Domestic recovery of secondary indium remained low for the 4th year since the unusually high level of 1996, when high prices encouraged the recycling of more old scrap. In 2000, as is typical in the United States, most of the secondary indium was recovered from new scrap. The actual quantity of secondary indium recovered is not known, but it was small; only in 1996 was the quantity significant following a $12 per troy ounce price increase in 1995 that resulted from concern over supply. In 1996, recycling provided much of domestic supply (Fineberg, 1996), and imports decreased more than 50%.

In Japan, however, recycling has maintained its importance in recent years (McColloch, 2000). In 2000, indium demand reached a record 335 t in 2000 in Japan, with slightly more than one-half of the material coming from recycled scrap (Roskill's Letter from Japan, 2001).

Iron and Steel[11]

Iron, including its refined product steel, is the most widely used of all the metals, and the recycling of iron and steel scrap (ferrous scrap) is an important activity worldwide. Iron and steel products are used in many construction and industrial applications, such as in appliances, bridges, buildings, containers, highways, machinery, tools, and vehicles. Because it is economically advantageous to recycle iron and steel by melting and recasting into semifinished forms for use in the manufacture of new steel products, a significant industry has developed to collect used and obsolete iron and steel products, and the ferrous scrap generated in steel mills and steel-product manufacturing plants. The North American steel industry's overall recycling rate is nearly 64% (Steel Recycling Institute, [undated], A few facts about steel—North America's #1 recycled material, accessed August 23, 2001, at URL http://www.recycle-steel.org/fact).

The vast quantity of ferrous scrap available for recycling comprises home, prompt, and obsolete scrap. Prompt, or industrial, scrap is generated from manufacturing plants that make steel products. Its chemical and physical characteristics are known, and it is usually transported quickly back to steel plants for remelting to avoid storage space and inventory control costs. Home or mill scrap is generated within the steel mill during production of iron and steel. Trimmings of mill products and defective products are collected and quickly recycled back into the steel furnace because their chemical compositions are known. The availability of home scrap has been declining as new and more efficient methods of casting have been adopted by the industry. Obsolete, old, or post-consumer scrap is also available for recycling. The largest source is junked automobiles, followed by demolished steel structures, wornout railroad cars and tracks, appliances, and machinery. Because of the wide variety of chemical and physical characteristics, obsolete scrap requires more preparation, such as sorting, detinning, and dezincing.

In the United States, the primary source of obsolete steel is the automobile (Steel Recycling Institute, [undated], Recycling scrapped automobiles, accessed August 23, 2001, at URL http://www.recycle-steel.org/cars/autorec.html). Of the ferrous metal used to make a typical 2000 U.S. family vehicle, about 44% was recycled metal. About 12,000 car dismantlers and 3,000 scrap processors produced more than 14 Mt of iron and steel scrap from about 14 million automobiles for recycling in 2000—enough steel to produce 48 million steel utility poles, which are one-third of the utility polls in the United States (Steel Recycling Institute, [undated], Recycling scrapped automobiles, accessed August 23, 2001, at URL http://www.recycle-steel.org/cars/autorec.html).

Manufactured steel products have a wide range of physical and chemical characteristics according to relative contents of the trace elements carbon, chromium, cobalt, manganese, molybdenum, nickel, silicon, tungsten, and vanadium. Also, some steel products are coated with aluminum, chromium, lead-tin alloy, tin, or zinc. For these reasons, scrap dealers must carefully sort the scrap they sell and steelmakers must be careful to purchase scrap that does not contain undesirable elements, or residuals, that exceed acceptable levels, which vary according to the product being produced.

Steel mills melt scrap in basic-oxygen furnaces (BOF), electric arc furnaces (EAF), and to a minor extent, in blast furnaces. The proportion of scrap in the charge in a BOF is limited to less than 30%, whereas that in an EAF can be as much as 100%. Steel and iron foundries use scrap in EAFs and cupola

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furnaces. In 1999, BOFs were used to produce 53% of total steel in the United States while using only 28% of total scrap consumed (American Iron and Steel Institute, 2000, p. 86). During the same period, EAFs produced 47% of total steel while using 71% of total scrap consumed. Scrap was also melted in blast furnaces and other types of furnaces.

Iron and steel scrap is an additional resource for steelmakers that is more than just economically beneficial. Recycling conserves natural resources, energy, and landfill space. Recovery of 1 t of steel from scrap conserves an estimated 1,030 kg of iron ore, 580 kg of coal, and 50 kg of limestone. Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States (about 18 million homes) for 1 year (Steel Recycling Institute, [undated], Recycling scrapped automobiles, accessed July 17, 2000, at URL http://www.recycle-steel.org/cars/autorec.html).

During 1999, steel recycling rates were 95% for automobiles, 95% for construction structural beams and plates, 84% for appliances, 58% for steel cans, and nearly 64% overall (Steel Recycling Institute, [undated], A few facts about steel—North America's #1 recycled material, accessed August 23, 2001, at URL http://www.recycle-steel.org/fact).

Ferrous scrap is an important raw material for the steel and foundry industries. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars and consumer durables, and manufacturing operations, the mature industrialized economies are the main exporters of scrap. The main trade flows of scrap are from the heavily industrialized and developed countries of North America and Europe to lesser developed steelmaking countries. The United States was not the leading exporting country of iron and steel scrap in 1999, as reported by the International Iron and Steel Institute (2000, p. 102). Germany took the lead, followed by Russia, the United States, Ukraine, Japan, France, the United Kingdom, and the Netherlands. The four most significant importing nations were, in decreasing order of importance, Turkey, the Republic of Korea, and the United States (International Iron and Steel Institute, 2000, p. 104).

The U.S. trade surplus for all classes of ferrous scrap was 2.2 Mt in 2000 (U.S. Census Bureau, unpub. data, 2000). Total U.S. exports of carbon steel and cast-iron scrap went to 55 countries and totaled 4.5 Mt. The largest tonnages went to the Republic of Korea, Canada, Mexico, China, and Taiwan. Total U.S. exports of stainless steel scrap went to 43 countries and consisted of 470,000 t. The largest tonnages went to the Republic of Korea, Taiwan, Canada, and Japan. U.S. exports of alloy steel scrap (excluding stainless steel) were shipped to 46 countries and consisted of 815,000 t. The largest tonnages went to Canada and Mexico.

Lead[12]

About 77% of the 1.46 Mt of refined lead produced in the United States in 2000 was recovered from recycled scrap, of which a major source was spent lead-acid storage batteries. The recycled batteries consisted of the starting-lighting-ignition type used in automotive applications, as well as the industrial-type used in numerous applications such as uninterruptible power-supply equipment, load-leveling equipment for commercial electrical power systems, industrial forklifts, mining vehicles, golf cars and other human and materials transport vehicles, lawn equipment, airport ground-support equipment, floor sweepers and scrubbers, and bicycles. About 5% of the recycled lead was recovered from other lead-based sources including solder, cable covering, building construction materials, and drosses and residues (new scrap) from primary smelter-refinery operations.

Recycled lead was produced domestically by 18 companies operating 26 lead recovery plants. Of the 1.12 Mt of lead recycled in 2000, about 98% was produced by 7 companies operating 15 secondary smelter-refineries in Alabama, California, Florida, Indiana, Louisiana, Minnesota, Missouri, New York, Pennsylvania, Tennessee, and Texas. Most of the recycled lead was recovered either as soft lead or lead alloys to be reused in the manufacture of lead-acid storage batteries. Consumption of lead in storage batteries accounted for 87% of the reported consumption of lead in the United States in 2000.

During the period 1996 to 2000, the United States exported an average of about 92,000 t/yr of lead-bearing scrap, including battery as well as nonbattery forms. Only minimal quantities of lead-bearing scrap were imported during this period. The spot price for smelters' heavy soft lead scrap averaged about 21 cents per pound during this period. The average North American Producer price for refined lead was about 45 cents per pound.

During 2000, the recovery of lead from spent lead-acid batteries and other lead scrap at secondary smelters was sufficient to meet about 76% of the demand for lead in the manufacture of new batteries. The market price for whole scrap batteries averaged about 5.5 cents per pound near the end of 2000, translating to a lead price of 11 cents per pound, assuming that lead accounted for about 50% of battery weight. The failure rate of automotive batteries remained fairly level during most of the year, as sustained temperature extremes were absent in the more heavily populated regions of the United States. In December, however, extreme winter conditions in many parts of the United States increased the level of automotive battery failures, but the usual associated increase in demand for lead by the battery manufacturers was tempered by the high level of inventories of new replacement batteries held by the manufacturers. Production of lead at secondary smelters increased by about 2% compared with production in 1999. Stocks of refined secondary lead held by producers and battery manufacturers increased appreciably at yearend.

In January, Johnson Controls, Inc., Milwaukee, WI, signed new tolling agreements to recover lead from spent lead-acid batteries for its battery business on the west coast of the United States. Reportedly, the processing of the spent battery units was to be divided between the secondary smelter plants of RSR Corp. at City of Industry, CA, and GNB Technologies, Inc. at Vernon, CA. The tolling agreements were expected to be in effect for 1 year (Ryan's Notes, 2000a).

Exide Corp., Reading, PA, closed its Laureldale, PA, battery manufacturing plant at the end of June. According to company officials, the action was taken as a consolidation measure, thus achieving higher capacity utilization at its remaining battery manufacturing plants (Ryan's Notes, 2000b).

In late September, Exide Corp. completed its acquisition of GNB Technologies, Inc., Atlanta, GA. As a result of the purchase, and following shareholder approval, Exide Corp. was

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renamed Exide Technologies. GNB had supplied a significant portion of the industrial batteries used in the North American market. Thus, the purchase allowed Exide to reenter the North American industrial battery business. GNB also was a leading supplier of automotive batteries for both the original equipment and replacement battery markets. Following the acquisition, Exide also announced several initiatives designed to restructure the newly formed company: consolidation of automotive battery manufacturing facilities in the United States; consolidation of industrial battery operations in Europe; closure of several distribution centers and branch locations by the end of 2000; and downsizing and relocation of new headquarters to Princeton, NJ, from Reading, PA (Exide Technologies, 2000).

In December, Exide Technologies, Princeton, NJ, reported plans to reopen and upgrade its battery manufacturing plant in Maple, Ontario. Exide expected to produce industrial-type lead-acid batteries at the plant for the growing motive power and telecommunications markets. One type of battery to be produced at the Maple plant is used as a back-up power source for Internet and wireless driven voice, data, and multimedia networks. The company had closed the Maple plant, originally used to manufacture automotive-type lead-acid batteries, after Exide's acquisition of GNB Technologies, Inc. Exide's investment in the plant will extend over a 12-month period with initial production expected early in 2001 and full production by yearend (Platt's Metals Week, 2000).

Magnesium[13]

New magnesium-base scrap typically is categorized into one of four types. Type I is high-grade scrap, generally material such as gates, runners, and drippings from diecasting operations that is uncontaminated with oils. Types II, III, and IV are lower graded materials. Type II is oil-contaminated scrap, type III is dross from magnesium-processing operations, and type IV is chips and fines. The most desirable type of scrap is type I. Most of the type I scrap is generated during diecasting magnesium alloys. This scrap is either reprocessed at the diecasting facility or sold to a scrap processor. The other types of scrap are either sold to a scrap processor or are used directly in steel desulfurization. Old magnesium-base scrap, or postconsumer scrap, consists of such material as automotive parts, helicopter parts, lawnmower decks, used tools, and the like. This scrap is sold to scrap processors.

In addition to magnesium-base scrap, significant quantities of magnesium are contained in aluminum alloys that also can be recycled. Although some magnesium is lost in scrap processing, a significant quantity of the magnesium is recycled with the aluminum alloy. New aluminum-base scrap that is recycled consists, in descending order of importance, primarily of solids, borings and turnings, dross and skimmings, and other material, which includes foil and can-stock clippings. Because the main aluminum product that contains magnesium is beverage cans, the principal magnesium-containing, aluminum-base scrap is can-scrap skeleton from lids and can sheet clippings. This represents about one-half of the overall magnesium-containing, aluminum-base scrap.

Old aluminum-base scrap consists of a variety of materials, but the most important magnesium-containing component is UBCs. Because of the high recycling rate, UBCs represent about three-quarters of the magnesium-containing, old aluminum-base scrap that is reprocessed. The magnesium in old and new aluminum-base scrap is not separated from the aluminum alloy when it is recycled; rather, it is retained as an alloying component.

Magnesium scrap arrives at the recycler either loose on a dump trailer or in boxes on a van-type trailer. Sorting the magnesium-base scrap correctly is crucial to producing a product that meets specifications. Because magnesium and aluminum closely resemble each other, a load of magnesium scrap may contain some aluminum scrap as well. The scrap is visually inspected, and one of the ways to separate the magnesium from the aluminum scrap is by scratching the metal with a knife. Magnesium tends to flake, whereas the softer aluminum tends to curl. After separating the aluminum-base scrap and any other foreign material, the magnesium scrap is sorted according to alloy.

In melting, sorted scrap is charged to a steel crucible, which is heated to 675° C. As the scrap at the bottom begins to melt, more scrap is added. The liquid magnesium at the bottom is covered with a flux or inhibitive gas to control surface burning. After any alloying elements are added, such as aluminum, manganese, or zinc, and melting is complete, molten magnesium is transferred to ingot molds by hand ladling, pumping, or tilt pouring (Wentz and Ganim, 1992).

In addition to melting, magnesium scrap may be recycled by direct grinding of the scrap into powder for iron and steel desulfurization applications. This method is limited to using only specific types of clean scrap. Drosses and other contaminated scrap are not used because they can introduce impurities into the finished product, and these types of scrap can increase the danger of fire in the direct grinding (Dahm, 2000).

Manganese[14]

Scrap recovery specifically for manganese is insignificant. To a large extent, it is recycled incidentally as a minor component within scrap of another metal, particularly steel and, to a much lesser degree, aluminum. High-manganese (Hadfield) steel, which has a manganese content of about 12%, is recovered for its manganese content, but the quantity of such scrap is believed to be well below 1% of the total quantity of purchased steel scrap. Recycling of aluminum and steel are discussed in the respective sections of this chapter. Manganese is ubiquitous throughout the various grades of steel, which, on average, contains about 0.7% manganese (Jones, 1994, p. 10). Manganese that is recycled to steelmaking within steel scrap largely is lost because of its removal in the decarburization step of steelmaking, but needs to be added back. Manganese is recycled in the aluminum industry as a component of scrap of certain manganese-bearing aluminum alloys, principally as UBC in which the manganese content is about 1%. Melting and processing of aluminum is nonoxidizing toward manganese, so that most of the manganese is retained. The amount of manganese being recycled in the aluminum industry is estimated to be in the vicinity of 1% of manganese apparent consumption.

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In the future, small additional amounts of manganese could be recovered through widespread recycling of dry cell batteries (Watson, Andersen, and Holt, 1998).

Mercury[15]

In response to health and environmental concerns, secondary mercury is recovered from a variety of source materials as mandated by Federal and State regulations to reduce the discharge and disposal of mercury-containing products. Electronic devices including rectifiers, switches, thermostats, and relays; dental amalgams; batteries; and other instruments such as thermometers, are processed to recover any contained mercury. However, the largest source of secondary mercury remains the spent catalysts used in the production of chlorine and caustic soda. Three companies, one each in Illinois, Minnesota, and Pennsylvania, produce the bulk of secondary mercury in the United States. Mercury waste generated in the manufacturing of products (new scrap) is either reused internally or collected for reprocessing.

Molybdenum[16]

Catalysts containing about 3,400 t of molybdenum were recycled. The U.S. superalloys producers consumed about 460 t of pure molybdenum metal scrap. Also molybdenum contained in alloy iron and steel scrap was recycled to produce new alloyed steel products. The amount of molybdenum consumed to produce these products was not recorded.

Nickel[17]

Austenitic stainless steel scrap is the largest source of secondary nickel for the United States, accounting for about 83% of the 84,000 t of nickel reclaimed in 2000. An additional 2% came from the recycling of alloy steel scrap. The combined 85% represents not only scrap used in raw steel production, but also lesser amounts of scrap consumed by steel and iron foundries, as well as nickel reclaimed from stainless steelmaking residues (e.g., furnace dust, grindings, and mill scale).

Western World demand for austenitic scrap increased substantially in the first half of 2000 because of higher prices for primary nickel. The price rise and global scrap drawdown were the result of a shortage of cathode and briquets. In the second half of 2000, recessionary forces in the United States triggered a dropoff in domestic stainless steel production and a slackening of deliveries of austenitic scrap to U.S. steelworks. The U.S. steel industry produced a near-record 1.24 Mt, gross weight, of austenitic stainless steel in 2000 despite the second half dropoff. Production of austenitic stainless steel in the European Union (EU) and Japan rose to 3-year highs, spurring international trade in austenitic scrap (Hunter, 2001).

Demand in the Western World for primary nickel was estimated to be a record 1.029 Mt in 2000, up slightly from 1.004 Mt in 1999 (International Nickel Study Group, 2001a, p. 3-12). The Western World supply of primary nickel also increased, but lagged behind demand for the second consecutive year (see Nickel chapter). A shortage of cathode and briquets caused prices to rise at the beginning of 2000. The monthly LME cash price for 99.8% pure nickel peaked at $10,280 per metric ton in March and then gradually declined during the remainder of the year to finish at $7,314 per metric ton. The gradual price decline was attributed to the buildup of recessionary forces in the United States and parts of East Asia. Prices for austenitic scrap in Pittsburgh closely tracked the LME price and also gradually declined during the last half of the year.

Russia and the United States continued to be the largest exporters of stainless steel scrap. The huge influx into Western Europe of Russian stainless steel scrap and nickel alloy scrap, which began in 1995, slackened in the first half of 1999 after the Russian Government imposed a new tariff on scrap metal exports. Nickel and six other scrap metals were subject to the 20% export tariff (Reuters Ltd., 2000a, b). In November 1999, the tariff was raised to 30% (Interfax International Ltd., 2000a). Because of the tariff and low prices for cathode at the time, Russian exports of stainless steel scrap fell 9% between 1998 and 1999, dropping from 343,000 t (gross weight) to 313,000 t (International Nickel Study Group, 2001b, p. 79). Russian scrap exports recovered in the second half of 1999 in response to higher nickel prices and continued to rise throughout 2000. (See Figure 1.) At yearend 2000, nickel in scrap was being quoted in Europe at 84% of the LME cash price. Discounts in the United States were greater than those in Europe, with U.S. scrap prices equivalent to about 77% of LME nickel values. Discounts began 2000 on both continents at 88%.

The Russian Government extended its 5% export tariff on refined nickel into 2000 and later raised it to 10%. The new tariffs and regulations left nonferrous scrap brokers in a more precarious position than the primary producers. In March 2000, the Russian Ministry of Economics proposed raising the 30% tariff on scrap to 50%—to curb excessive exports (Interfax International Ltd., 2000b; Reuters Ltd., 2000a, b). Federation officials also were evaluating new procedures for levying value-added taxes on exports. The entire policy of levying tariffs on exports was debated in the Federal Council, the upper house of the Russian Parliament.

Inmetco converts a variety of nickel and chromium wastes at Ellwood City, PA, into a remelt alloy suitable for stainless steelmaking. The Ellwood City operation was set up in 1978 to reclaim chromium and nickel from emission control dusts, swarf, grindings, mill scale, and other wastes generated by the stainless steel industry. Over the past 22 years, Inmetco has made a number of improvements to its Pennsylvania facility and now also processes nickel- and/or chromium-bearing filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries.

ELG Haniel GmbH handled about 1.2 Mt of stainless steel scrap worldwide in 1999, up 9% from that of 1998. About 790,000 t was sold to steelworks in Germany and other EU member countries. The company moved the scrap processing facilities of Jewometaal, its Dutch subsidiary, to a new location in the Port of Rotterdam. Jewometaal spent Eur 8 million, or about $7.7 million, on the new recycling and transshipment facilities (ELG Haniel GmbH, 2000, p. 32-33).

U.S. industry recycles a broad spectrum of other nickel-bearing materials in addition to stainless steel. Copper-nickel alloy scrap and aluminum scrap accounted for about 10% of the

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nickel reclaimed in 2000. Scrap in this category comes from a myriad of sources and includes cupronickel (a series of copper alloys containing 2% to 45% Ni), the Monels (a group of alloys typically containing 65% Ni and 32% Cu), nickel-silver (a misnomer for a series of copper-zinc-nickel alloys), and nickel-aluminum bronze. Cupronickel is stronger and more resistant to oxidation at high temperatures than pure copper, making it desirable for saltwater piping and heat exchanger tubes. Nickel-silver—a white brass—is used for rivets, screws, camera parts, and optical equipment. The aerospace industry uses 2218, 2618, 4032, 8280 and several other wrought aluminum alloys that contain 0.2% to 2.3% nickel.

The remaining 8% of reclaimed nickel came from pure nickel scrap and nickel-base alloy scrap. Superalloy producers and downstream fabricators of turbine engines and chemical processing equipment generate a large part of this material—some of which is sent to scrap processors for salvaging and cleaning and later returned to the producers for remelting. However, because of the stringent specifications for INCONEL 718, WASPALOY, and similar aerospace-grade superalloys, much of the superalloy scrap is not suitable for direct recycling and is sold to stainless steel producers, steel foundries, or specialty alloy casting companies. Significant amounts of superalloy scrap are intentionally generated during the forging and machining of turbine parts for aircraft engines. As little as 1 out of 7 kg of superalloy may end up in a finished turbine part (Lane, 1998). Superalloy scrap is an important source of revenue for most aerospace machine shops. Proper segregation of turnings and grindings, on-site recovery of cutting fluids, and timely shipping of the scrap can make the difference between profitability and bankruptcy for a small- to medium-size machine shop. Inclusion of a pea-size piece of a lead, bismuth, or tungsten alloy can put an entire truckload of superalloy scrap out of specification. Aircraft engine repair facilities are an important source of obsolete superalloy scrap.

Demand for superalloy scrap reached record levels in 2000. Three factors contributed to the tightness of supply. First, manufacturing of land-based gas turbines increased dramatically as power companies rushed to meet growing demand for electrical power, especially on the West Coast of the United States. Second, orders for new jet aircraft engines and other aerospace components picked up after a 2-year downturn. Third, several processors of superalloy scrap were operating at maximum capacity. Low prices for primary nickel in 1998 and 1999 had discouraged the scrap industry from adding new processing capacity in 2000. A major problem was inadequate capacity to process turnings from machine shops. Turnings are one of the larger sources of superalloy scrap, but require considerable processing. Scrap processors must crush, sample, clean, densify, and package the turnings before they can be shipped to the buyer (Newman, 2001).

To help relieve the tightness in the superalloy scrap market, Keywell LLC set up a new processing facility in Los Angeles, CA, in early 2000. The Los Angeles facility became operational in the second half of 2000 and has begun consolidating shipments for forwarding to Keywell's Vac Air Alloys Division at Frewsburg, NY. The Frewsburg facility reportedly is the largest processor of vacuum-grade superalloy and titanium scrap in the world. In March, Keywell also opened a new facility in Fairless Hills, PA, to process stainless steel scrap in bulk.

Superalloy scrap processors now have to compete with stainless steel blenders and nickel-cobalt refineries for the scrap. The ongoing expansion of the Airbus consortium is expected to increase superalloy arisings in Western Europe. To date, superalloy melters have shied away from Russian aerospace scrap. Traditional Russian aerospace grades are difficult to blend with Western alloys because of differences in chemical composition. These problems may disappear as Russia begins producing more Western-equivalent grades of superalloys.

The U.S. collection and recycling program for NiCd and nickel-metal hydride (NiMH) batteries is in a period of rapid expansion. Federal legislation passed in 1996 has helped spur the program. The program is administered by Rechargeable Battery Recycling Corp. (RBRC), a nonprofit public service corporation funded by more than 285 manufacturers and marketers of portable rechargeable batteries and battery-operated products (Millard, 1999). The program is primarily designed to recycle the more than 75 million small, sealed, rechargeable NiCd batteries sold annually to U.S. and Canadian businesses and consumers for use in cordless products. RBRC licensees now account for four out of five NiCd sales in North America. Almost 25,000 retail outlets or community collection sites in the United States accept spent NiCd batteries. Some 4,500 collection sites in Canada also participate in the RBRC program. The bulk of the collected batteries are sent to Inmetco for reclamation.

In Western Europe, the portable battery market grew from 2.8 billion units in 1985 to almost 4.9 billion units in 1995, an increase of 70%. This increase has led to renewed concerns in the EU about the inclusion of NiCd batteries in municipal waste going to landfills or incinerators. About 62% of the municipal waste in the EU is currently landfilled; another 19% is incinerated. In March 2001, the European Commission drafted a directive that calls for the phase out of cadmium in portable batteries by January 1, 2008. Special exemptions were proposed for batteries used in medical devices, emergency equipment, and special scientific instrumentation. The proposed directive also would establish a minimum recycling target of 55% for all collected batteries. More costly NiMH and lithium-ion batteries would be substituted for the NiCds. Some 13,000 t of portable NiCd batteries averaging 15% cadmium (Cd) and 3,500 to 4,000 t of industrial NiCd batteries averaging 6% Cd are marketed annually in the EU. Industry studies show that only 11% of the portable NiCd batteries were being reclaimed compared with 53% of the industrial batteries (Commission of the European Communities, 2001).

A proposal by the U.S. Department of Energy (DOE) to decontaminate 6,000 t of radioactively contaminated nickel was opposed by a large part of the metals industry. The House Committee on Commerce also expressed its concerns to DOE. The Metals Industry Recycling Coalition has taken the position that no metal originating from Nuclear Regulatory Commission (NRC)-licensed fuel cycle and DOE-operated facilities should be released for unrestricted recycling or reuse even if the levels of radioactivity are within "safe" levels specified by the NRC. The Steel Manufacturers Association took legal action to delay an NRC rule that would have allowed the material to be decontaminated and recycled back to the public. Other coalition members included the Specialty Steel Industry of North America, the American Iron and Steel Institute, the Nickel Development Institute, and the Copper and Brass Fabricators

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Council (Kelly, 1999).

Platinum-Group Metals[18]

Despite their limited availability, platinum-group metals (PGM), and chemical compounds containing them, are widely used as catalysts in the chemical and petroleum industries as well as used in electrical conductors, extrusion devices, dental and medical prostheses, and jewelry. Since 1998, platinum has been used in the manufacture of computer hard disks. Moreover, since the beginning of the 1975 model year, new automobiles sold in the United States have been equipped with PGM-based (primarily platinum) catalytic converters to remove polluting substances from engine exhausts.

For most PGM applications, the actual loss during use of the metal is small, and hence the ability to recover the metal efficiently contributes greatly to the economics of PGM use. Typical sources of PGM for secondary refining include catalysts, electronic scrap, jewelry, and used equipment, e.g., from the glass industry. Spent automotive catalysts have emerged as the leading source of secondary PGM. The United States has the world's most developed network for recycling spent autocatalysts; most domestic scrap yards systematically remove catalytic converters from scrapped vehicles. Although smaller vehicle dismantlers have considered it uneconomical to collect the catalysts, the rise in PGM prices prompted many of them to begin removing catalytic converters for the first time in 2000. This development led to an increase in the amount of platinum recovered—from about 9,800 kg in 1999 to about 10,900 kg in 2000. In recent years, palladium catalysts have become more widely used in catalytic converters for motor vehicles. An estimated 4,700 kg of palladium was recovered in 2000.

Selenium[19]

Most selenium, except that applied to the surfaces of the photoreceptor drums in plain paper copiers, is dissipated as process waste or is eventually sent to a landfill as a minor constituent of a used product. The small quantities that are added to glass as a decolorant and to ferrous and nonferrous metal alloys to improve metalworking properties are not recovered in the recycling of those materials and are probably volatilized during remelting. Selenium rectifiers, once a major source of old scrap, generally have been replaced by silicon rectifiers. Additionally, current high processing costs have made it uneconomical to recover selenium from the scrapped rectifiers that are available.

In 2000, no secondary selenium was recovered in the United States. Wornout photoreceptor drums and scrap generated in the manufacture of new drums were exported for the recovery of the selenium content. An estimated 50 t of secondary selenium was imported; this was about 10% of all selenium imports. Practically all the selenium used in photoreceptor drums is recovered through very efficient recycling programs (Hoffman and King, 1997, p. 704). Secondary selenium was recovered in Canada, Europe, Japan, and the Philippines. The photocopier market for selenium, still the main feed source for secondary selenium, continued its decline owing to competition from other technologies, mainly organic photoreceptors.

Hydromet Environmental Recovery Ltd. will accept waste material for the recovery of selenium and tin at its new plant scheduled to open during 2001 in Newman, IL. The plant expects to process selenium materials from the copper refining and photocopy industries (American Metal Market, 2000b).

Silver[20]

About 1,680 t of silver, valued at $270 million, was recovered from scrap in 2000. Photographic scrap was estimated to have generated 1,300 t of silver; the largest part was recovered from spent fixer solution, x ray and graphic arts wastes, and a small quantity directly from color film wastes. The remainder was recovered from jewelers' sweepings, spent catalysts, electronic scrap, and other heterogeneous silver bearing materials. Recovered silver accounted for about one-fourth of industrial demand in 2000.

Tantalum[21]

Tantalum is ductile, easily fabricated, highly resistant to corrosion by acids, and a good conductor of heat and electricity and has a high melting point. The major use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. More than 60% of total tantalum consumed is in the electronics industry. Major end uses for tantalum capacitors include portable telephones, pagers, personal computers, and automotive electronics. Alloyed with other metals, tantalum is also used in making carbide tools for metalworking equipment and in the production of superalloys for jet engine components. Substitutes such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually used at either a performance or economic penalty.

In 2000, U.S. apparent consumption of tantalum totaled about 650 t, with consumed scrap (from various sources) accounting for an estimated 20% of the total. Recycling of tantalum, mostly from new scrap, takes place largely within the processing and end-product industries. In addition, quantities of tantalum are recycled in the form of used tantalum-bearing cutting tools and high-temperature alloy melting scrap. Tantalum recycled from finished electronic components (old scrap) is very small and not yet fully developed. However, new scrap materials reclaimed at manufacturing plants that produce tantalum-related electronic components are a major source of tantalum supply and are delivered back to tantalum processors for recycling (Cunningham, 1985, 2001b; Tantalum-Niobium International Study Center, 1996).

Tin[22]

In 2000, about 30% of the domestic apparent supply of tin metal was recovered from scrap (table 1). Old tin scrap is collected at hundreds of domestic scrap yards, five detinning

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plants, and most municipal collection-recycling centers. New tin scrap is generated mainly in the tin mills of six steel plants, scores of canmaking facilities, numerous brass and bronze plants, and many soldermaking operations. Most tin-scrap-processing facilities are close to the tin-using industries and to densely populated markets in the Midwest and the Northeast.

Detinning facilities are unique to the tin scrap industry in that no other major metal industry has numerous large-scale plants to remove plated metal. Detinning operations are performed on new tinplate scrap from tin mills or canmaking plants and on old tinplate scrap in the form of used tin cans. For most of the past century, the detinning process has been the only technique in the secondary tin industry by which free tin metal returns to the marketplace. The bulk of the secondary tin industry works with the various alloy forms of tin (brass, bronze, solder, etc.); the tin is recycled within its own product-line industries and thus reappears in regenerated alloys.

The Steel Recycling Institute (SRI) continued to promote the recycling of used tin cans, which has become an important raw material for the nation's steel industry during the past 15 years. SRI announced that the domestic steel can recycling rate had remained about the same in 2000 as in 1999 at 58%, compared with 56% in 1998, and 15% in 1988 (Steel Recycling Institute, 2001).

Tin scrap prices are rarely published, but generally approximate the prices for primary tin metal.

Titanium[23]

Titanium scrap is primarily used as an alternative to titanium sponge in the production of titanium ingot. Common forms of titanium scrap include turnings and bulk weldables (bars, billet cutoffs, plate trimmings, etc.). Titanium scrap is generated during the melting, forging, casting, and fabrication of titanium components. "New scrap" is generated during the production and fabrication of titanium components, while "old scrap" is recovered from used components (old aircraft parts, heat exchangers, submarine hulls, etc.).

Currently, over one-half of the titanium feedstock for ingot production is derived from scrap. Scrap is recycled into titanium ingot with or without virgin metal by using either vacuum-arc-reduction or cold-hearth melting practices. Titanium ingot producers in France, Germany, Japan, Russia, the United Kingdom, and the United States lead the recycling of titanium scrap. In the United States, titanium ingot producers (recyclers) included Allegheny Technologies Inc., Howmet International, Lawrence Aviation Industries Inc., RMI Titanium Co., and Titanium Metals Corp. Numerous companies were involved in the generation, segregation, and processing of scrap for recycling.

In 2000, U.S. production of titanium ingot decreased 3% compared with that of 1999. Scrap supplied about 50% of the titanium required for ingot production, somewhat less than the 55% supplied in 1999. Although no data are available as to the percentage breakdown of sources of titanium scrap, less than 2% of titanium ingot production is estimated to be derived from old scrap.

Although consumption of titanium metal by commercial aircraft producers remained relatively high from an historical perspective, recycling of titanium scrap decreased by about 9% compared with that of 1999. While imports of titanium scrap increased 9% compared with those of 1999, exports decreased 38%. In contrast to 1999, the United States was a net exporter of titanium scrap in 2000, with exports exceeding imports by 2,490 t.

In addition to that recycled by ingot producers, titanium scrap is consumed by the steel and nonferrous alloy industries. It should be noted that imports and exports of titanium scrap include material to be recycled back into titanium components and that consumed by steel and nonferrous alloys.

Consumption by the steel industry is largely associated with the production of stainless steels and is used for deoxidation, grain-size control, and carbon and nitrogen control and stabilization. In steelmaking, titanium is introduced as a ladle addition normally in the form of ferrotitanium because ferrotitanium has a lower melting point and has a higher density than scrap. Ferrotitanium is produced from titanium and steel scrap by induction melting.

World ferrotitanium production capacity is estimated to be 64,000 t, led by, in descending capacity order, the United Kingdom, Russia, Japan, and the United States. In 2000, there were three domestic producers of ferrotitanium: Global Titanium, Inc., Detroit MI; Galt Alloys Inc., North Canton, OH; and ShieldAlloy Inc., Newfield, NJ. In addition to domestic producers, numerous companies are involved in the import and trade of ferrotitanium.

In the nonferrous metals industry, titanium scrap is primarily consumed to produce aluminum-titanium master alloys for the aluminum industry. When used in aluminum alloys, titanium improves casting and reduces cracking.

Owing to a moderate drop in demand, prices for unprocessed titanium scrap turnings (Ti-6AL-4V) decreased from about $1.10 per pound at yearend 1999 to $0.78 per pound at yearend 2000. Yearend prices for ferrotitanium prices decreased from about $2.40 per pound in 1999 to $1.59 per pound in 2000.

Future consumption of titanium scrap is largely dependent on demand for titanium metal products by the aerospace industry. Over the next decade, titanium demand by the aerospace industry is expected to exceed 5%; however, growth in the aerospace industry is cyclical. Growth in the consumption of ultra low carbon steels for automotive applications and appliances is expected to increase demand for ferrotitanium. Given the long-term growth trend for ferrotitanium imports, imports are expected to meet much of the future domestic demand for ferrotitanium.

Tungsten[24]

In 2000, an estimated 25% to 30% of world tungsten supply was from recycled materials (Maby, 1999, p. 4). Tungsten-bearing scrap originates during manufacture and/or after use in the following applications: cemented carbides used for cutting and wear-resistant applications; mill products made from metal powder, such as filaments and electrodes for lamps and heavy metal alloys; and alloys, such as tool steels, high-speed steels, and superalloys. Depending on the type and quality of the scrap,

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it can be recycled by the industry sector that generated it, used as a source of tungsten by another consuming industry, or used as a substitute for tungsten concentrate by tungsten processors (Smith, 1994, p. 4-14).

Cemented carbide scrap is recycled by several processes. Some of these processes result in tungsten carbide powder combined with cobalt, which can be used to make new cemented carbide parts. In other processes, the cobalt is recovered separately, and the tungsten is converted to the intermediate product ammonium paratungstate from which tungsten carbide powder, chemicals, or metal powder can be produced. Tungsten metal scrap from the manufacture of mill products is used to make cast carbides, ferrotungsten, superalloys, and tool steel. It can also be processed chemically to produce ammonium paratungstate. Most heavy metal alloy manufacturing scrap is recycled as home scrap to a prealloyed powder, but it can also be chemically converted to ammonium paratungstate or used to produce tool steel (Kieffer, 1982, p. 102-107). Steel scrap and superalloy scrap are recycled by the steel and superalloys industries, respectively.

In 2000, scrap consumption reported by U.S. tungsten processors and consumers was 5,120 t of contained tungsten, an increase of 3% from the 4,980 t (revised) consumed in 1999. The United States imported 993 t of tungsten contained in waste and scrap, valued at $6.2 million, 31% less than the tungsten content of waste and scrap imports in 1999. Five countries supplied 70% of these imports—China, 25%; the Republic of Korea and Russia, 15% each; Germany, 8%; and Japan, 7%. U.S. exports of tungsten waste and scrap were an estimated 827 t of contained tungsten valued at $4.4 million, which was approximately equal to the estimated tungsten content of waste and scrap exports in 1999. The leading destinations for these exports were Germany, 48%; Taiwan, 10%; China, 7%; Canada; 6%; and Belgium, 5%.

Vanadium[25]

Vanadium is used primarily as an alloying element. Very small quantities of vanadium, often less than 1%, are alloyed with other metals to produce various ferrous and nonferrous alloys. Owing to the relatively small amount of vanadium involved, these alloys in general do not lend themselves to recycling for vanadium recovery. Vanadium is also used as a catalyst. It is estimated that catalyst consumption accounts for less than 1% of the total U.S. vanadium consumption. However, processing spent vanadium catalysts accounts for the only significant source of refined secondary vanadium. Three plants in Arkansas, Louisiana, and Texas accounted for most of the recycled vanadium catalyst. Any new scrap generated in either the production of alloys or catalysts is likely reused internally.

Zinc[26]

In 2000, about 30% of world's zinc production was produced from secondary materials—brass, die casting scrap, flue dust, galvanizing residues, zinc sheet, etc. In the United States, more than one-fourth of the 1.61 Mt consumed by domestic industries is secondary zinc. More than three-quarters of recycled zinc was derived from new scrap generated mainly in galvanizing and die casting plants and brass mills. The remaining one-quarter was obtained from brass products, flue dust, old die casts, and old rolled zinc articles. Recycled zinc was used by 3 primary smelters and 12 large and medium (more than 1,000 t/yr) sized secondary smelters primarily for production of zinc chemicals, mainly oxide, and zinc metal, including alloys. In addition, there is a changing number of smaller companies that usually produce zinc chemicals. IMCO Recycling Inc., Midwest Zinc Corp., and Zinc Corp. of America are the largest U.S. recyclers of zinc.

Because of wide differences in the character and zinc content of scrap, the recycling processes of zinc-bearing scrap vary widely. Clean new scrap, mainly brass, rolled zinc clippings, and rejected die castings, usually requires only remelting. In the case of mixed nonferrous shredded metal scrap, zinc is separated from other materials by hand or magnetic separation. Most of the zinc recovered from EAF dust, produced during remelting of galvanized steel scrap, is recovered in rotary kilns by using the Waelz process. Because the most common use of zinc is for galvanizing, the latest research is aimed mainly at stripping zinc from galvanized steel scrap before remelting.

In 2000, trade in zinc scrap was small—about 2% of total domestic consumption. Nearly 93% of imported zinc scrap was supplied by Canada, and the major destination of U.S. exports was Taiwan (51%). Prices for scrap varied according to quality, presence of other components, geographic location, and environmental difficulties in handling, transporting, or treating. The price for a ton of zinc metal contained in scrap was about three-fourths of the LME price for refined zinc metal.

Zirconium[27]

Zirconium scrap comprises about one-fourth to one-third of the feedstock for ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of zirconium components. In addition, some obsolete or old scrap is recycled from dismantled process equipment, vessels, heat exchangers, etc. Although no data are available as to the percentage breakdown of sources of scrap, it is estimated that less than 2% of ingot production is derived from old scrap. Prior to melting, scrap must be analyzed, classified, and processed to remove impurities. Several companies have proprietary processes to accomplish this task. Scrap is initially melted without virgin metal by the two domestic ingot producers, Wah Chang, a subsidiary of Allegheny-Teledyne Corp., Albany, OR, and Western Zirconium, a subsidiary of Westinghouse Electric Co., Ogden, UT, using vacuum-arc-reduction melting practices.

References Cited

Aluminum Association Inc., 2001, Americans recycle 2 of 3 aluminum cans: Washington, DC, Aluminum Association Inc. press release, April 19, 4 p.
American Iron and Steel Institute, 2000, Annual report 2000: American Iron and Steel Institute, August, 130 p.
American Metal Market, 2000a, DLA taps two for electronic scrap contracts:

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American Metal Market, v. 107, no. 53, March 16, p. 8.
———2000b, Hydromet ready to take waste for metal recovery operations: American Metal Market, v. 108, no. 243, December 19, p. 10.
Commission of the European Communities, 2001, European Parliament and Council directive on batteries and accumulators (draft): Brussels, Commission of the European Communities, March 30, 53 p.
Cunningham, L.D., 1985, Tantalum, *in* Mineral Facts and Problems: U.S. Bureau of Mines Bulletin 675, p. 811-822.
———2001a, Beryllium: U.S. Geological Survey Mineral Commodity Summaries 2001, p. 30-31.
———2001b, Tantalum: U.S. Geological Survey Mineral Commodity Summaries 2001, p. 164-165.
Dahm, M.R., 2000, Preparation of secondary magnesium for use in hot metal desulfurization, *in* Stewart, D.L., Jr., Stephens, R.L., and Daley, J.C., eds., International Symposium—Recycling of Metals and Engineered Materials, 4th, Pittsburgh, PA, October 22-25, 2000, Proceedings: Warrendale, PA, Minerals, Metals, & Materials Society, p. 1333-1340.
ELG Haniel GmbH, 2000, Annual report—1999: Duisburg, Germany, ELG Haniel GmbH, January, 74 p.
Exide Technologies, 2000, Exide completes acquisition of GNB Technologies: Reading, PA, Exide Technologies news release, September 29, 4 p.
Fineberg, Seth, 1996, Indium can't find bottom; growth in recycling: American Metal Market, v. 104, no. 201, October 16, p. 1.
Hoffman, J.E., and King, M.G., 1997, Selenium and selenium compounds, *in* Kirk-Othmer encyclopedia of chemical technology, (4th ed.): New York, John Wiley & Sons, v. 21, p. 686-719.
Hunter, B.A., 2001, The globalized picture of stainless steel scrap: 2001 Annual Meeting of the International Nickel Study Group, The Hague, The Netherlands, April 25-27, Handout, 11 p.
Interfax International Ltd., 2000a, Economics Ministry wants to raise export duties on nonferrous scrap: Interfax International Ltd., Mining and Metals Report, v. 9, no. 13 (418), March 24-30, p. 21.
———2000b, Russia to raise export duties on nonferrous scrap to 50%: Interfax International Ltd., Mining and Metals Report, v. 9, no. 33 (438), August 11-17, p. 3.
International Copper Study Group, 2001, Copper bulletin: Lisbon, International Copper Study Group, v. 8, no. 9, 48 p.
International Iron and Steel Institute, 2000, Steel statistical yearbook 2000: International Iron and Steel Institute, December, 111 p.
International Nickel Study Group, 2001a, World nickel statistics—Monthly bulletin: The Hague, International Nickel Study Group, v. 11, no. 9, September, 80 p.
———2001b, World nickel statistics—Monthly bulletin (Special issue): The Hague, International Nickel Study Group, v. 11, no. 11, November, 87 p.
Jones, T.S., 1994, Manganese material flow patterns: U.S. Bureau of Mines Information Circular 9399, 57 p.
Kelly, N.E., 1999, SMA leads coalition against radioactive scrap, *in* Steel mini-mills supplement: American Metal Market, v. 107, no. 231, December 2, p. 6A.
Kieffer, B.F., 1982, Recycling systems with particular reference to the zinc process, *in* Tungsten—1982: International Tungsten Industry Association, San Francisco, CA, June 1-5, Proceedings, p. 102-114.
Kramer, D.A., 1988, Gallium and gallium arsenide—Supply, technology, and uses: U.S. Bureau of Mines Information Circular, 25 p.
Lane, John, 1998, Recycling of superalloys for gas turbines *in* Superalloys for gas turbines, Tampa, FL, June 15-17, 1998, Proceedings: Gorham, ME, Gorham Advanced Materials Inc., 7 p.
Maby, Michael, 1999, Market report by the Secretary-General, *in* Tungsten—Advanced technology & new applications: International Tungsten Symposium, 8th, Fukuoka, Japan, October 12-15, 1999, Transcripts of Papers, 15 p.
McColloch, Russ, 2000, Indium displays a bright future: Metal Bulletin Monthly, no. 357, September, p. 55-57.
Millard, Ralph, 1999, RBRC Ni-Cd recycling program update, *in* Battery Waste Management—Past, Present and Future, 11th International Seminar and Exhibit, Deerfield Beach, FL, November 1-3, 1999, Proceedings: Boca Raton, FL, Florida Educational Seminars, Inc., 16 unpaginated view graphs.
Newman, E.J., 2001, Superalloy scrap demand reaching record levels: American Metal Market, Superalloys Supplement, v. 109, no. 166, August 27, p. 11.
Papp, J.F., 1991, Chromium, nickel, and other alloying elements in U.S.-produced stainless and heat-resisting steel: U.S. Bureau of Mines Information Circular 9275, 41 p.
Petkof, Benjamin, 1985, Beryllium, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 75-82.
Platt's Metals Week, 2000, Exide to reopen battery plant: Platt's Metals Week, v. 71, no. 51, December 18, p. 14.
Platts Metals Week, 2001, Platt's Metals Week annual metal averages for 2000: Platts Metals Week, v. 72, no. 6, February 5, p. 18.
Reuters Ltd., 2000a, No big change seen in Russian duties: Reuters Ltd., April 4, 2 p.
———2000b, Russian stainless exports on upswing?: Reuters Ltd., February 9, 1 p.
Roskill's Letter from Japan, 2001, Indium—Record Japanese demand in 2000: Roskill's Letter from Japan, no. 296, April, p. 10-11.
Ryan's Notes, 2000a, JCI's new west coast tolling contracts: Ryan's Notes, v. 6, no. 2, January 10, p. 4.
———2000b, Lead and zinc—Exide to close Laureldale SLI plant: Ryan's Notes, v. 6, no. 10, March 6, p. 3.
Smith, G.R., 1994, Materials flow of tungsten in the United States: U.S. Bureau of Mines Information Circular 9388, 23 p.
Southwire Co., 2000, Southwire to close copper refinery and sell aluminum smelter: Carrollton, GA, Southwire Co. news release, April 4, 2 p.
Steel Recycling Institute, 2001, Steel recycling rate continues moderate ascent: Pittsburgh, PA, Steel Recycling Institute news release, April 10, 2 p.
Tantalum-Niobium International Study Center, 1996: Tantalum-Niobium International Study Center, no. 86, June, p. 1-11.
Watson, N.J., Andersen, R.W., and Holt, G., 1998, Battery recycling in the metals industry from Europe to the USA, *in* International Seminar on Battery Waste Management, 10th, Deerfield Beach, FL, October 26-28, 1998, Proceedings: Boca Raton, FL, Florida Educational Seminars Inc., unpaginated.
Wentz, Harold, and Ganim, Larry, 1992, Recycling—The catchword of the 90's—Recycling of magnesium: Light Metal Age, v. 50, nos. 1 and 2, February, p. 14-21.
World Metal Statistics, 2001, World Bureau of Metal Statistics, London: World Metal Statistics, v. 54, no. 8, p. 42.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Mineral Commodity Summaries, annual.
Mineral Industry Surveys, monthly and annual.
Minerals Yearbook, annual.
United States Mineral Resources, Professional Paper 820, 1973.

Other

Aluminum Association Inc. Aluminum Statistical Review, annual.
Aluminum Metal Monitor (monthly report of Commodities Research Unit Ltd. (CRU)).
American Bureau of Metal Statistics (ABMS) Non-Ferrous Metal Data.
American Metal Market, daily.
Battery Council International, special reports.
Brass and Bronze Ingotmakers Association.
Copper and Brass Fabricators Council, Inc.
Institute of Scrap Recycling Industries.
Lead and Zinc Statistics (monthly bulletin of the International Lead and Zinc Study Group).
Metal Bulletin (London).
Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platts Metals Week.
Resource Recycling.
Roskill Information Services Ltd. Zinc 1997, 6th Ed.
U.S. Department of Commerce News.

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TABLE 1
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

Year	Quantity of metal (metric tons)					Value of metal (thousands)			
	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 5/	Percent recycled	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 6/
Aluminum: 7/									
1996	1,730,000	1,570,000	3,310,000	8,340,000	40	$2,730,000	$2,480,000	$5,200,000	$13,100,000
1997	2,020,000	1,530,000	3,550,000	8,740,000	41	3,430,000	2,590,000	6,020,000	14,800,000
1998	1,950,000	1,500,000	3,440,000	9,040,000	38	2,810,000	2,160,000	4,970,000	13,100,000
1999 r/	2,120,000	1,570,000	3,700,000	9,890,000	37	3,070,000	2,280,000	5,350,000	14,300,000
2000	2,080,000	1,370,000	3,450,000	9,610,000	36	3,420,000	2,260,000	5,670,000	15,800,000
Chromium: 8/									
1996	NA	NA	98,400	468,000 r/	21.0 r/	NA	NA	96,000 r/	651,000 r/
1997	NA	NA	120,000	489,000 r/	24.5	NA	NA	122,000 r/	716,000 r/
1998	NA	NA	104,000	524,000 r/	19.8 r/	NA	NA	91,500 r/	612,000 r/
1999	NA	NA	118,000	558,000	21.2	NA	NA	77,700 r/	533,000 r/
2000	NA	NA	139,000	589,000	23.6	NA	NA	98,600	587,000
Copper: 9/									
1996	891,000	428,000	1,320,000	3,720,000	35.4	2,140,000	1,030,000	3,170,000	8,950,000
1997	967,000	498,000 r/	1,460,000	3,900,000 r/	37.5 r/	2,380,000 r/	1,170,000	3,450,000	9,210,000 r/
1998	956,000	466,000	1,420,000	3,980,000	35.7	1,660,000	808,000	2,470,000	6,900,000
1999	949,000 r/	381,000	1,330,000	4,080,000	32.7	1,590,000	637,000 r/	2,220,000 r/	6,820,000
2000	952,000	363,000	1,310,000	4,060,000	32.4	1,850,000	705,000	2,550,000	7,890,000
Iron and steel: 10/									
1996	NA	NA	71,000,000	121,000,000	59	NA	NA	9,270,000	15,800,000
1997	NA	NA	73,000,000	127,000,000	58	NA	NA	9,520,000	16,500,000
1998	NA	NA	73,000,000	133,000,000	55	NA	NA	7,910,000	17,400,000
1999	NA	NA	71,000,000	130,000,000	55 r/	NA	NA	6,680,000	12,300,000
2000	NA	NA	74,000,000	134,000,000	55	NA	NA	7,100,000	12,800,000
Lead: 11/									
1996	37,500	1,020,000	1,050,000	1,660,000	63.7	40,400	1,090,000	1,140,000	1,790,000
1997	54,000	1,030,000	1,090,000	1,660,000	65.4	55,400	1,060,000	1,120,000	1,700,000
1998	45,800	1,050,000	1,100,000	1,740,000	63.1	45,700	1,050,000	1,100,000	1,740,000
1999	42,700	1,050,000	1,090,000	1,790,000	60.9	41,200	1,010,000	1,050,000	1,730,000
2000	35,400	1,080,000	1,120,000	1,790,000	62.6	34,000	1,040,000	1,080,000	1,720,000
Magnesium: 12/									
1996	41,100	30,100	71,200	205,000	35	170,000	125,000	295,000	850,000
1997	47,000	30,500	77,600	233,000	33	172,000	112,000	284,000	851,000
1998	45,200	31,800	77,100	226,000	34	158,000	111,000	284,000	788,000
1999	52,000 r/	34,200 r/	86,100 r/	231,000 r/	37 r/	178,000 r/	117,000 r/	294,000 r/	789,000 r/
2000	52,200	30,100	82,300	209,000	39	158,000	90,800	248,000	630,000
Nickel: 13/									
1996	NA	NA	59,300	206,000	28.8	NA	NA	445,000	1,540,000
1997	NA	NA	68,400	222,000	30.8	NA	NA	474,000	1,540,000
1998	NA	NA	63,100	212,000	29.7	NA	NA	292,000	983,000
1999	NA	NA	71,000	211,000	33.6	NA	NA	427,000	1,270,000
2000	NA	NA	84,000	231,000	36.4	NA	NA	725,000	1,990,000
Tin: 14/									
1996	3,930	7,710	11,600	37,400	31	35,600	69,900	106,000	339,000
1997	4,540	7,830	12,400	48,600	25	38,200	65,600	104,000	409,000
1998 15/	8,470	7,790	16,300	54,600	30	69,600	64,000	134,000	449,000
1999 15/	8,650	7,720 r/	16,400 r/	57,300 r/	29 r/	70,400 r/	62,800 r/	133,000 r/	466,000 r/
2000 15/	8,450	6,600	15,100	52,100	29	68,800	53,700	122,000	424,000
Titanium: 16/									
1996	NA	NA	26,300	W	48	NA	NA	50,700 e/	NA
1997	NA	NA	28,200	W	46	NA	NA	37,600 e/	NA
1998	NA	NA	28,600	W	50	NA	NA	22,100 e/	NA
1999	NA	NA	21,900	W	55	NA	NA	28,900 e/	NA
2000	NA	NA	18,500	W	50	NA	NA	38,200 e/	NA
Zinc: 17/									
1996	266,000	113,000	379,000	1,450,000	26.1	274,000	114,000	388,000	1,640,000
1997	286,000	89,700	376,000	1,490,000	25.2	376,000	118,000	495,000	1,960,000
1998	344,000	89,900	434,000	1,580,000	27.5	352,000	92,100	444,000	1,620,000
1999	321,000	78,100 r/	399,000 r/	1,610,000	24.8 r/	379,000 r/	92,200 r/	471,000 r/	1,900,000 r/
2000	369,000	66,900	436,000	1,610,000	27.1	454,000	85,600	540,000	2,060,000

See footnotes at end of table.

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TABLE 1--Continued
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Scrap that results from the manufacturing process, including metal and alloy production. New scrap of aluminum, copper, lead, tin, and zinc excludes home scrap. Home scrap is scrap generated and recycled in the metal producing plant.
3/ Scrap that results from consumer products.
4/ Metal recovered from new plus old scrap.
5/ Apparent supply is production plus net imports plus stock changes. Production is primary production plus recycled metal. Net imports are imports minus exports. Apparent supply is calculated on a contained weight basis.
6/ Same as apparent supply defined in footnote 5 above but calculated on a monetary value basis.
7/ Scrap quantity is the calculated metallic recovery from purchased new and old aluminum-base scrap, estimated for full industry coverage. Monetary value is estimated based on average U.S. market price for primary aluminum metal ingot.
8/ Chromium scrap includes estimated chromium content of stainless steel scrap receipts (reported by the iron and steel and pig iron industries) where chromium content was estimated to be 17%. Trade includes reported or estimated chromium content of chromite ore, ferrochromium, chromium metal and scrap, and a variety of chromium-containing chemicals. Stocks include estimated chromium content of reported and estimated producer, consumer, and Government stocks. Recycled value calculated from quantity using the average annual import value of high-carbon ferrochromium. Apparent supply value calculated from quantity using average annual trade value.
9/ Includes copper recovered from unalloyed and alloyed copper-base scrap, as refined copper or in alloy forms, as well as copper recovered from aluminum-, nickel-, and zinc-base scrap. Monetary value based on annual average refined copper prices.
10/ Iron production measured as shipments of iron and steel products plus castings corrected for imported ingots and blooms. Secondary production measured as reported consumption. Apparent supply includes production of raw steel. Monetary value based on U.S. annual average composite price for No. 1 heavy melting steel calculated from prices published in American Metal Market.
11/ Lead processors are segregated by primary and secondary producers. This segregation permits inclusion of stock changes for secondary producers. Monetary value of scrap and apparent supply estimated based upon average quoted price of common lead. Excludes copper-based scrap.
12/ Includes magnesium content of aluminum-base scrap. Monetary value based on the annual average Platt's Metals Week's U.S. spot Western price.
13/ Nickel statistics were derived from the following:

Canvass data
- •Reported nickel content of products made from reclaimed stainless steel dust, spent nickel-cadmium batteries, plating solutions, etc.
- •Estimated nickel content of reported net receipts of alloy and stainless steel scrap.
- •Reported nickel content of recovered copper-base scrap.
- •Reported nickel content of obsolete and prompt purchased nickel-base scrap.
- •Estimated nickel content of various types of reported obsolete and prompt aluminum scrap.

Trade data
- •Reported nickel content of International Nickel Study Group (INSG) Class I primary products, including cathode, pellets, briquets, powder, and flake.
- •Reported or estimated nickel content of INSG Class II primary products, including ferronickel, metallurgical-grade nickel oxide, and a variety of nickel-containing chemicals.
- •Estimated nickel content of secondary products, including nickel waste and scrap and stainless steel scrap.

Stock data
- •Reported or estimated nickel content of all scrap stocks, except copper.
- •Reported nickel content of primary products held by world producers in U.S. warehouses.
- •Reported nickel content of primary products held by U.S. consumers.
- •Reported nickel content of U.S. Government stocks.

Monetary value based on annual average cash price for cathode, as reported by the London Metal Exchange.
14/ Monetary value based on Platt's Metals Week Composite price for tin.
15/ 1998 to 2000 new scrap data include data unavailable for 1996 and 1997.
16/ Percentage recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.
17/ Monetary value based on annual average Platt's Metal Week metal price for North American special high-grade zinc.

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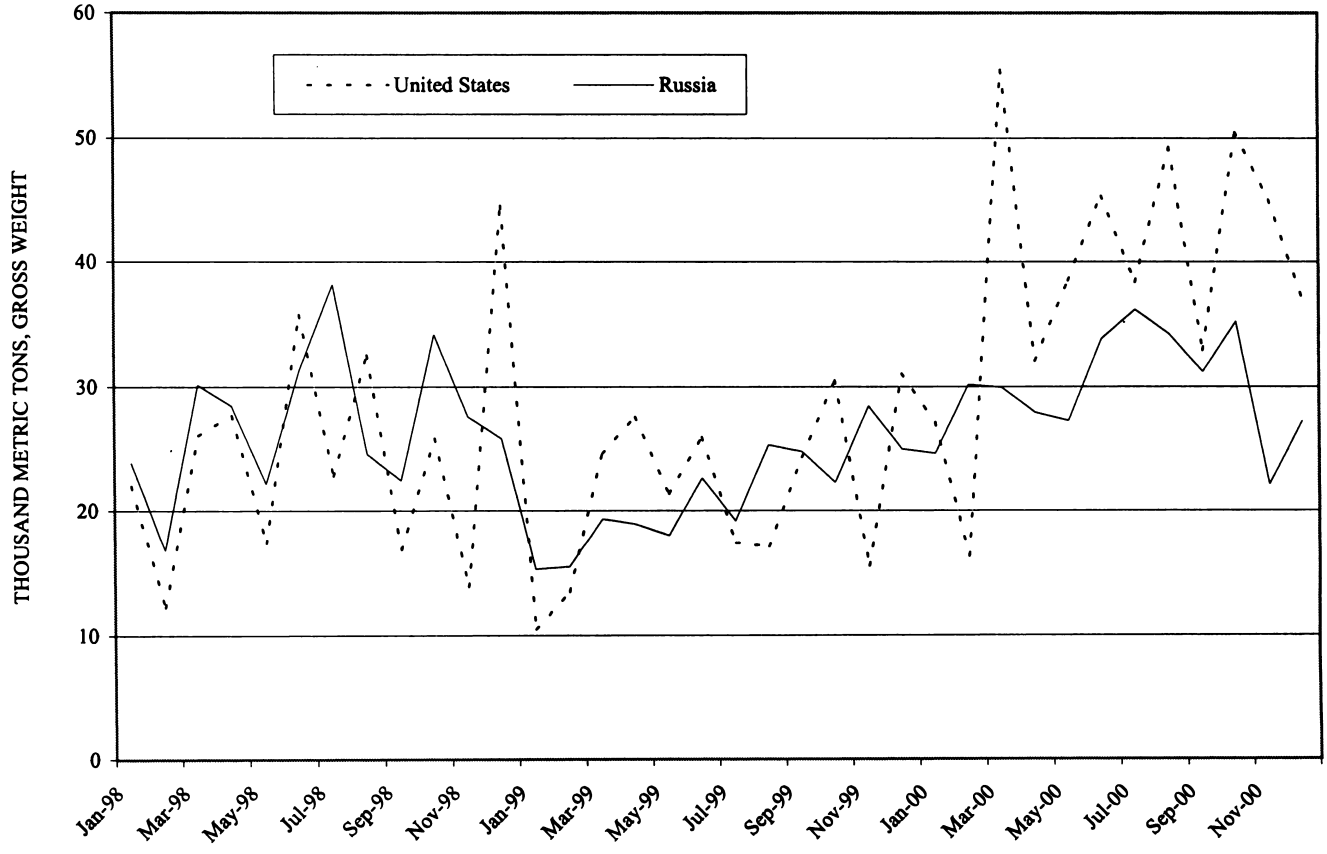
FIGURE 1
EXPORTS OF STAINLESS STEEL SCRAP--RUSSIA AND UNITED STATES



Source: International Nickel Study Group. Russian export data as reported by importing countries.

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RHENIUM

By John W. Blossom

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In the past decade, the two most important uses of rhenium have been in platinum-rhenium catalysts and high-temperature superalloys. Platinum-rhenium catalysts are used to produce lead-free, high-octane gasoline. Superalloys are used for turbine engine components. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse; these included thermocouples, heating elements, temperature controls, flashbulbs, vacuum tubes, x-ray tubes and targets, metallic coatings, and electrical contact points. Research by industry continued on the recovery of rhenium from ore and concentrate and the development of new catalysts and alloys.

In the United States, rhenium is a byproduct of molybdenite recovered as a byproduct of porphyry copper ore from six operating porphyry copper-molybdenum-rhenium mines in the Western States. Domestic mine production data for rhenium (table 1) were derived by the U.S. Geological Survey from reported molybdenum production at the mines. Domestic demand for rhenium metal and other rhenium products was met principally by imports, but also from domestic recovery and stocks.

Compared with that of 1999, 2000 rhenium consumption decreased by about 1.5%; imports of metal for consumption decreased by 16% and imports of ammonium perrhenate increased by 171% (table 1). The average prices for metal powder and ammonium perrhenate were $1,009 and $514 per kilogram, respectively.

Consumption

Rhenium is used in petroleum-reforming catalysts for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Rhenium catalysts tolerate greater amounts of carbon formation in making gasoline and make it possible to operate the production process at lower pressures and higher temperatures, which leads to improved yields (production per unit of catalyst used) and higher octane ratings. In 2000, catalytic uses comprised about 20% of rhenium consumption reported in table 1. Platinum-rhenium catalysts also were used in the production of benzene, toluene, and xylenes, although this use was small compared with that of gasoline production.

A significant property of rhenium is its ability to alloy with molybdenum and tungsten. Molybdenum alloys containing about 50-weight-percent rhenium have greater ductility and can be fabricated by either warm or cold working. Unlike other molybdenum alloys, this type of alloy is ductile at temperatures above 196° C and can be welded. Alloys of tungsten with 24-weight-percent rhenium have improved ductility and have lower ductile-to-brittle transition temperatures than pure tungsten. Rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). In 2000, metallurgical uses comprised about 75% of rhenium consumption. Other uses for these alloys, which collectively represented only 5% of total consumption, were in thermocouples, temperature controls, heating elements, ionization gauges, mass spectrographs, electron tubes and targets, electrical contacts, metallic coatings, vacuum tubes, crucibles, electromagnets, and semiconductors.

Foreign Trade

Imports for consumption of rhenium metal are listed in tables 1 and 2, and those of ammonium perrhenate are listed in tables 1 and 3. World production of rhenium in ore was estimated to be 28 metric tons (t); the quantity of rhenium recovered is

Rhenium in the 20th Century

Following the discovery of rhenium in 1925, the usual investigative work to isolate sufficient quantities, determine its properties, and locate adequate sources began. Rhenium remained little more than a curiosity until the latter half of the century.

In 1956, after several years of development, Kennecott Copper Corp. began producing rhenium at Washington, PA, where Molybdenum Corp. of America roasted Kennecott's Bingham Canyon Mine molybdenite concentrates. No more than 4,600 kilograms of rhenium was produced in the Western World between 1942 and 1965, with most used in research and development. Industrial use was small, mostly metallurgical, in high temperature thermocouples and some electronic uses.

In the late 1960s, the use of rhenium in catalysts began when both Chevron, Inc., and UOP, Inc., developed the bimetallic platinum-rhenium reforming catalysts. The first charge of catalyst was installed in Chevron's El Paso, TX, refinery. The price of rhenium escalated to $1,870 per kilogram in 1969 and to a high of $3,080 per kilogram in 1971. These high prices of 1971 and 1972 stimulated competition with rhenium in the form of indium and germanium catalysts. Rhenium prices have fluctuated widely since that time.

In 2000, metallurgical applications returned to being the major use because of usage by the turbine engine industry. The estimated U.S. consumption of rhenium in 2000 was about 32,000 kilograms of metal.

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estimated to have been about 25 t, because not all concentrates were processed to recover the rhenium values. Rhenium was recovered from some byproduct molybdenite concentrates from porphyry copper deposits in Canada, Chile, China, Iran, Kazakhstan, Peru, Russia, and the United States. Rhenium metal and compounds were produced in Chile, France, Germany, Russia, the United Kingdom, and the United States.

World Review

World reserves of rhenium are contained primarily in molybdenite in porphyry copper deposits. U.S. reserves of rhenium are concentrated in Arizona, New Mexico, and Utah. Chilean reserves are found primarily at four large porphyry copper mines and in lesser deposits in the northern one-half of the country. In Peru, reserves are concentrated primarily in the Toquepala open pit porphyry copper mine and in about 12 other deposits in the rest of the country.

Other world reserves are in several porphyry copper deposits and sedimentary copper deposits in Armenia, northwestern China, Russia, and Uzbekistan and in sedimentary copper-cobalt deposits in the Congo (Kinshasa).

Technology Development

The feasibility of introducing rhenium as an in situ diffusion barrier to reduce the loss of aluminum from an aluminum diffusion barrier coating has been investigated by researchers at Hokkaido University, Sapporo, Japan. The results were reported at the NACE Corrosion 2001 conference in Houston, TX. Rhenium is added to superalloys to improve creep resistance. In addition, slow diffusion of rhenium has been shown to be responsible for slower coarsening kinetics in single crystals. In the study, a nickel-base single crystal superalloy containing rhenium was aluminum-diffusion treated, then oxidized in air at 1,373 K for up to 2.54 megaseconds under thermal cycling and isothermal conditions. The treatment was carried out in a mixture of FeAl and Al_2O_3 powder. It resulted in a triplex layer structure in the sequence beta NiAl/Re rich layer/Al diffusion zone (Narita, 2001).

Outlook

In the next 5 years, demand for rhenium metal was expected to follow the demand for turbine engines and petroleum. For the long term (10 to 20 years), recycling of rhenium-bearing waste and scrap was expected to increase. Identified U.S. resources are estimated to be about 7,000 t, and identified rest-of-world resources are estimated to be about 10,000 t.

Reference Cited

Narita, Toshio, 2001, Application of rhenium coatings as a diffusion barrier to improve high temperature oxidation resistance of nickel-based superalloys: Advanced Materials and Processes, v. 159, no. 5, May, p. 20-21.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Rhenium. Ch. in Minerals Commodity Summaries, annual.
Rhenium. Ch. in Minerals Yearbook, annual.
Rhenium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Rhenium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT U.S. RHENIUM STATISTICS 1/

(Gross weight, kilograms)

	1996	1977	1998	1999	2000
Mine production 2/	14,000	15,400	14,000	12,000	12,600
Consumption e/	24,100	17,900	28,600	32,500	32,000
Imports (metal)	10,800	8,510	14,200	12,800	10,700
Imports (ammonium perrhenate)	10,000	6,560	11,000	2,750	7,450

e/ Estimated.
1/ Data are rounded to no more than three significant digits.
2/ Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY 1/

	1999		2000	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	--	--	23	$24
Chile	10,100	$11,200	9,850	10,100
Estonia	31	15	40	32
Germany	1,650	1,990	300	260
Romania	--	--	22	13
Russia	785	516	136	83
Switzerland	--	--	36	38
United Kingdom	209	258	291	259
Total	12,800	14,000	10,700	10,800

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY 1/

	1999		2000	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Chile	829	$689	--	--
China	270	71	--	--
Estonia	470	243	151	$61
Germany	--	--	183	129
Kazakhstan	1,070	610	6,100	2,970
Russia	109	61	--	--
United Kingdom	--	--	1,010	671
Total	2,750	1,670	7,450	3,830

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

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TABLE 4
RHENIUM: ESTIMATED WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country	1996	1997	1998	1999	2000
Armenia	NA	NA	1,000	700	700
Canada	1,500	--	2,200	1,600	1,600
Chile	2,600	2,500	2,500	2,400	2,200
Kazakhstan	200	1,800	2,400	2,400	2,400
Peru	2,000	2,000	2,300	4,800	4,800
Russia	500	NA	900	1,100	1,100
United States 3/	14,000	15,400	14,000	12,000	12,600
Uzbekistan	300	NA	NA	NA	NA
Other	100	5,000	3,200	3,000	3,000
Total	21,200	26,700	28,500	28,000	28,400

NA Not available. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through September 2001.
3/ Calculated rhenium contained in MoS_2 concentrates. Recovered quantities are considerably less and are withheld.

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SALT

By Dennis S. Kostick

Domestic survey data and tables were prepared by Jeff Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Salt, also known as sodium chloride, is composed of the elements sodium and chlorine. Sodium is a silver-colored metal, which is so unstable that it reacts violently in the presence of water, and chlorine is a greenish-colored gas that is dangerous and lethal. Yet the combination of these two elements forms sodium chloride, which is a white-colored compound essential to life itself. Virtually every person in the world has some direct or indirect contact with salt daily. People routinely add salt to their food as a flavor enhancer or apply rock salt to walkways to remove ice in the winter. Salt is used as feedstock for chlorine and caustic soda manufacture; these two inorganic chemicals are used to make many consumer-related end-use products, such as polyvinyl chloride (PVC), a plastic made from chlorine and paper-pulping chemicals manufactured from sodium hydroxide (caustic soda).

Production

U.S. production data for salt are developed by the U.S. Geological Survey (USGS) from an annual voluntary survey of U.S. salt-producing sites and company operations. The four types of salt that are surveyed are classified according to the method of recovery: rock salt, from the surface or underground mining of halite deposits; solar salt, from the solar evaporation of seawater, landlocked bodies of saline water, or primary or byproduct brines; vacuum pan salt, from the mechanical evaporation of a purified brine feedstock; and brine, from the solution mining of underground halite deposits. Data for brine production and consumption represent the anhydrous salt content only and not the weight of the water.

The structure of the U.S. salt industry has changed throughout the years. In 1970, 50 companies operated 95 salt-producing plants in the United States. Market competition, energy and labor costs, less expensive imports, currency exchange rates, and an excess of production capacity (resulting in the downsizing of the industry through mergers and acquisitions) reduced the size of the industry to 32 companies and 69 plants by 2000. The information and data are fundamental resources for analysis both within and outside the Government. The salt data and information are needed by the public and private sectors to better understand minerals and materials use and the ultimate disposition of materials in the economy and in the environment and to develop public and private sector policies and practices that better utilize our mineral and material resources. Some of the clients that use the salt data and information are financial institutions, State and Federal agencies, salt-consuming industries (e.g., agricultural, chemical, and food processing), educational institutions, and the general public.

Of the 32 companies to which a survey request was sent, all but 3 responded, representing 95% of the total production shown in this report. Data for nonrespondents were estimated based on their prior responses to previous annual surveys, the 2000 production estimate survey, or brine production capabilities for chloralkali manufacture based upon published chlorine production capacities [1.75 metric tons (t) of salt required per ton of chlorine capacity].

Total U.S. salt production increased by 2% in 2000 to 45.6 million metric tons (Mt) compared with that of 1999. According to the USGS canvass for 2000, 32 companies operated 69 salt-producing plants in 15 States. Of these, 9 companies and 17 plants produced more than 1 Mt each and accounted for 90% and 69%, respectively, of total U.S. production and 90% and 33%, respectively, of total value. Several companies and plants produced more than one type of salt. In 2000, 11 companies (14 operations) produced solar-evaporated salt; 6 companies (18 operations), vacuum pan salt; 11 companies (16 operations), rock salt; and 13 companies (32 operations), salt brine (tables 1-3).

Salt in the 20th Century

In 1900, the United States led the world as the largest salt-producing country, representing about 23% of total world output, followed by the United Kingdom, France, the German Empire, and Italy. Imports of fine salt decreased to 6% of domestic consumption in 1900 from 37% in 1880, because U.S. salt manufacturers steadily increased their production of table, dairy, and other special grades of salt. The major uses of salt at that time were food applications for humans and animals, leather tanning, and fish and meat preservation; however, use of salt as a chemical feedstock was beginning to increase with the development of the first soda ash plant in Syracuse, NY, in 1884 and the first electrolytic chlorine facility in Rumford, ME, in 1892. Although the first domestic automobile was not invented until 1896, the use of salt for road deicing would not begin until the 1930s.

In 2000, the top five salt-producing nations that collectively accounted for 55% of total world output, in descending order of quantity produced, were the United States, China, Germany, India, and Australia. The United States was the largest salt-producing nation, representing about 22% of total world output. The five leading States, in terms of total salt sold or used, were Louisiana, Texas, New York, Kansas, and Utah. The chemical industry, primarily the chlorine and caustic soda sectors, was the largest consumer of salt. Salt for domestic synthetic soda ash manufacture declined and eventually ceased in the last quarter of the 20th century because of environmental and energy issues and competition from natural soda ash. Salt for human consumption, which had been a major end use in the past century, declined to about 3% of total domestic consumption.

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The five leading States in terms of total salt sold or used were Louisiana with 31%; Texas, 25%; New York, 13%; Kansas, 6%; and Utah, 5% (table 4). Other Eastern States (Alabama, Michigan, Ohio, Tennessee, and West Virginia) accounted for 17% of the domestic total salt sold or used. Other Western States (Arizona, California, Nevada, New Mexico, and Oklahoma) represented 3%.

Since the loss of the Retsof Mine in New York in 1995, progress continued on developing a new mine at Hampton Corners, NY. A group of investors formed American Rock Salt Co. LLC in 1997 and acquired the assets of the Retsof Mine, including a large salt stockpile, and mineral rights at Hampton Corners. On October 2, 1997, American Rock Salt shipped its first truckload of salt from the stockpile, while the company went forward with plans to sink a mineshaft to the underground salt formation. In late 1998, construction began on the mineshaft, and on November 18, 1999, salt was reached in the service shaft. On January 26, 2000, the first truckload of salt was delivered from the new mine. The mine was expected to reach its full capacity of 2.3 Mt by mid-2001 (American Rock Salt Co. LLC, 2001, Company biography and history, accessed May 22, 2001, via URL http://americanrocksalt.com).

In February, IMC Global Inc. announced it was interested in divesting its salt company IMC Salt Co. to refocus on its core crop-nutrient businesses. This divestment would include the rock salt operations in Louisiana and Canada, the vacuum pan salt plants in Kansas, and the solar salt facility in Utah (Chemical Market Reporter, 2000). In a cost-reduction effort, IMC closed its Hutchinson, KS, vacuum pan salt facility and increased vacuum pan salt production at its Lyons, KS, and Hersey, MI, plants (Bertram, 2000). Further capacity reductions in the domestic salt industry also occurred in late 1999 and into 2000, when Cargill Inc. closed its Redwood City, CA, solar salt plant, which had capacity of about 315,000 metric tons per year (t/yr).

Consumption

In 2000, apparent consumption (salt sold or used, plus imports, minus exports) was 51.6 Mt, whereas reported consumption (sales or use as reported by the salt companies including their imports and exports) was 54 Mt, which was an increase of 8% compared with that of 1999. Although these two measures of consumption are not necessarily supposed to be identical, they normally are similar. The 2.4-Mt difference between the two types of consumption for 2000 and 1999, however, can only be explained by stockpiling of imported salt by producers, distributors, and consumers during the year.

The direct and indirect uses of salt number about 14,000, according to industry sources. The USGS annually surveys 8 major categories comprising 29 end uses. The 2000 reported percentage distribution of salt by major end use was chemicals, 42%; ice control, 36%; distributors (grocery and other wholesalers and retailers, etc.), 7%; general industrial, 6%; agricultural, 4%; food processing, 3%; primary water treatment, 1%; and other uses combined with exports, 1%. Distributors represented a substantial share of salt sales by the salt industry; all of this salt is ultimately resold to many different end-users. For a more complete analysis of end-use markets, specific sectors of distribution in table 5 can be combined, such as agricultural and water treatment with agricultural and water conditioning distribution, respectively.

Aside from the different types of salt, there are various distinctions in the packaging and applications of salt. Salt for human consumption is packaged in different sized containers for several specialized purposes. Table salt may contain 0.01% potassium iodide as an additive, which provides a source of iodine that is essential to the oxidation processes in the body. Kosher salt, sea salt, condiment salt, and salt tablets are special varieties of salt.

Water conditioning and animal feed salt are made into 22.7-kilogram (50-pound) pressed blocks. Sulfur, iodine, trace elements, and vitamins are occasionally added to salt blocks to provide missing nutrients not found naturally in the diet of certain livestock. Salt is also compressed into pellets and used for water conditioning.

Chemical.—The largest consumer of salt, primarily salt brine, is the chemical industry. Within this industry, the chloralkali sector remains the major consumer of salt for manufacturing chlorine, coproduct sodium hydroxide, and synthetic soda ash. Since 1986, when the last synthetic soda ash plant closed because of high production costs and competition with less expensive natural soda ash, no synthetic soda ash has been manufactured in the United States; many countries, however, still produce synthetic soda ash and use vast quantities of salt brine as feedstock.

Salt is used as the primary raw material in chlorine manufacture because it is an inexpensive and widely available source of chlorine ions. For sodium hydroxide production, salt is the main source of the sodium ions. About 98% of the domestic chlorine and sodium hydroxide produced is obtained from the electrolysis of salt brine feedstock by using three-cell technologies. The types of cells and the percentages of chlorine manufactured by them are diaphragm, 78%; mercury, 14%; and membrane, 6%. The remaining 2% of chlorine and caustic soda production is recovered as a byproduct from magnesium and sodium metal manufacture.

It takes about 1.75 t of salt to make 1.0 t of chlorine and 1.1 t of coproduct caustic soda. The electrolytic process ionizes the sodium chloride compound and selectively allows the ions to migrate through special membranes. Chlorine gas forms at the anode, while sodium ions bond with water molecules at the cathode to form sodium hydroxide with hydrogen gas evolving.

Chlorine and caustic soda are considered to be the first generation of products made from salt. These two chemicals are further used to manufacture other materials, which are considered to be the second generation of products from salt. Although most salt brine is produced by the same companies that use it, many chloralkali manufacturers now purchase brine from independent brine supply companies. In certain cases, brine is produced by a chemical company that uses some of it and sells the excess to neighboring competitors. According to a survey of domestic salt-based chlorine facilities, about 48% of the salt used to manufacture chlorine was produced by manufacturing companies, and 31% was purchased brine. Solar salt, rock salt, and vacuum pan salt are also used to manufacture many chemicals (tables 5, 6).

In 2000, according to U.S. Census Bureau data, 12 Mt of chlorine and 11 Mt of sodium hydroxide (caustic soda or lye) were produced. Based on the industry average ratio of 1.75 t of salt required to produce 1.0 t of chlorine and 1.1 t of coproduct sodium hydroxide, the chlorine and caustic soda industry consumed about 21 Mt of salt for feedstock. Reported consumption of total domestic and imported salt for chlorine manufacture was 21.3 Mt (table 5). The difference between the calculated and reported quantities was the amount of salt not

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reported to the USGS from imports or captive brine production of chloralkali producers.

Salt also is used as a feedstock in chemical establishments that make sodium chlorate (by the electrolysis of an acidified salt brine using hydrochloric acid adjusted to a pH of 6.5), metallic sodium (by the electrolysis of a molten salt mixture containing 33.2% sodium chloride and 66.8% calcium chloride, which is added to reduce the melting temperature of salt), and other downstream chemical operations. In powdered soaps and detergents, salt is used as a bulking agent and a coagulant for colloidal dispersion after saponification. In pharmaceuticals, salt is a chemical reagent and is used as the electrolyte in saline solutions. It also is used with sulfuric acid to produce sodium sulfate and hydrochloric acid. This subsector is relatively small, representing only 5% of domestic salt sales for the entire chemical sector and only 2% of total domestic salt consumption.

The consumption of salt for metallic sodium has declined during the past several years. Since the 1970s, the number of producers has decreased from three to one; Ethyl Corp. and RMI Titanium Corp. exited the market in 1985 and 1992, respectively, leaving E. I. du Pont de Nemours & Co., Inc., as the sole manufacturer of metallic sodium in the United States. In 1998, the domestic market was less than 30,000 t having decreased from about 126,000 t in 1978. The phasing out of tetraethyl lead and tetramethyl lead gasoline additives were the main reasons for the decline in consumption. In 1978, sodium usage in gasoline represented about 80% of the domestic market. Although there is no information about sodium consumption in 2000, the largest use of sodium in 1998 was for sodium borohydride production, which is the feedstock for sodium dithionite that is used as a reductive bleaching agent by the pulp and paper industry and accounted for about 38% of metallic sodium consumption. Sodium metal also is used to manufacture sodium azide, which is used in automotive airbags. Other promising uses of sodium metal are in the remediation of chemical weapons, pesticides, polychlorinated biphenyls, and chlorofluorocarbons.

Ice Control and Road Stabilization.—The second largest end use of salt is for highway deicing. The developer of the Fahrenheit temperature scale discovered that salt mixed with ice at a temperature below the freezing point of water creates a solution (brine) with a lower freezing point than water by itself. The brine forms below the surface of the ice and snow and prevents the water from freezing into ice and bonding with the road surface, thus causing the snow and ice to melt. Salt is an inexpensive, widely available, and effective ice control agent. It does, however, become less effective as the temperature decreases below about -9.5° C to -6.5° C (15° F to 20° F). At lower temperatures, more salt would have to be applied to maintain higher brine concentrations to provide the same degree of melting. Most winter snowstorms and ice storms occur when temperatures are between -4° C and 0° C (25° F and 32° F), the range in which salt is most effective. An anticaking agent, such as ferric ferrocyanide (Prussian Blue) or sodium ferrocyanide (Yellow Prussiate of Soda), is used to prevent the salt from agglomerating. Both additives are nontoxic and harmless to humans. In fact, sodium ferrocyanide is approved for use in food-grade salt by the U.S. Food and Drug Administration (Food and Nutrition Board, 1966).

In highway deicing, salt has been associated with corrosion of motor vehicles, bridge decks, unprotected steel structures, and reinforcement bar and wire used in road construction. Surface runoff, vehicle spraying, and windblown actions also affect roadside vegetation, soil, and local surface- and ground-water supplies. Although evidence of environmental loading of salt has been found during peak usage, the spring rains and thaws usually dilute the concentrations of sodium in the area where salt was applied.

Salt is also added to stabilize the soil and to provide firmness to the foundation on which highways are built. The salt acts to minimize the effects of shifting caused in the subsurface by changes in humidity and traffic load.

The quantity of salt consumed for road deicing each year is directly related to the severity or mildness of the winter weather conditions. Long-range forecasting of salt consumption in this application is extremely difficult because of the complexities in long-range forecasting of the weather. Meteorologists, however, are becoming more aware of the dynamics of certain weather phenomena that influence the climate in various parts of the world. One of these phenomena is El Niño, which is now believed to be the largest single weather influence on Earth. The mild winters of 1997 and 1998 were attributed to El Niño effects. In 1998, highway deicing salt sales were the lowest since about 1992, which also was an El Niño year (National Broadcast Co., 1998, El Niño facts, accessed July 15, 1998, at URL http://wxnet4.nbcr.com/elnino.html). The winters of 1999 and 2000 were colder and produced more precipitation that required more salt for road deicing as shown in the rock salt production statistics in tables 1 and 2 and the rock salt consumption data in tables 5 and 6.

Distributors.—A tremendous amount of salt is marketed through various distributors, some of which specialize in markets such as agricultural and water treatment services, two sectors where the salt companies sell directly as well (table 5). Distributor sales also include grocery wholesalers and/or retailers, institutional wholesalers, U.S. Government resale, and other wholesalers and retailers.

General Industrial.—The industrial uses of salt are diverse. They include, in descending order, oil and gas exploration, textiles and dyeing, other industrial applications, metal processing, pulp and paper, tanning and leather treatment, and rubber manufacture.

In oil and gas exploration, salt is an important component of drilling fluids in well drilling. It is used to flocculate and increase the density of the drilling fluid to overcome high down-well gas pressures. Whenever a drill hits a salt formation, salt is added to the drilling fluid to saturate the solution and to minimize the dissolution within the salt strata. Salt is also used to increase the set rate of concrete in cemented casings.

In textiles and dyeing, salt is used as a brine rinse to separate organic contaminants, to promote "salting out" of dyestuff precipitates, and to blend with concentrated dyes to standardize them. One of its main roles is to provide the positive ion charge to promote the absorption of negatively charged ions of dyes.

In metal processing, salt is used in concentrating uranium ore into uranium oxide (yellow cake). It is also used in processing aluminum, beryllium, copper, steel, and vanadium.

In the pulp and paper industry, salt is used to bleach wood pulp. It also is used to make sodium chlorate, which is added along with sulfuric acid and water to manufacture chlorine dioxide, an excellent oxygen-based bleaching chemical. The chlorine dioxide process, which originated in Germany after World War I, is becoming more popular because of environmental pressures to reduce or eliminate chlorinated

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bleaching compounds.

In tanning and leather treatment, salt is added to animal hides to inhibit microbial activity on the underside of the hides and to replace some of the moisture in the hides. In rubber manufacture, salt is used to make buna, neoprene, and white types. Salt brine and sulfuric acid are used to coagulate an emulsified latex made from chlorinated butadiene.

Agricultural Industry.—Since prehistoric times, humankind has noticed that animals satisfied their salt hunger by locating salt springs, salt licks, or playa lake salt crusts. Barnyard and grazing livestock need supplementary salt rations to maintain proper nutrition. Veterinarians advocate adding loose salt in commercially mixed feeds or in block forms sold to farmers and ranchers because salt acts as an excellent carrier for trace elements not found in the vegetation consumed by grazing livestock; selenium, sulfur, and other essential elements are commonly added to salt licks, or salt blocks, for free-choice feeding.

Food Processing.—Every person uses some quantity of salt in their food. The salt is added to the food by the food processor or by the consumer through free choice, as a flavor enhancer, preservative, binder, fermentation-control additive, texture-control agent, and color developer. This major category is subdivided, in descending order of salt consumption, into meat packers, canning, other food processing, grain mill products, baking, and dairy.

In meat packing, salt is added to processed meats to promote color development in bacon, ham, and other processed meat products. As a preservative, salt inhibits the growth of bacteria, which would lead to spoilage of the product. Early pioneers stored their perishable food in salt barrels for protection and preservation. Salt acts as a binder in sausages to form a binding gel composed of meat, fat, and moisture. Salt also acts as a flavor enhancer and a tenderizer.

In the dairy industry, salt is added to cheese as a fermentation-control agent and as a color- and texture-control agent. The dairy subsector includes companies that manufacture creamery butter, natural and processed cheese, condensed and evaporated milk, ice cream, frozen desserts, and specialty dairy products.

In canning, salt is primarily added as a flavor enhancer and preservative. It also is used as a dehydrating agent, tenderizer, enzyme inhibitor, and carrier for other ingredients.

In baking, salt is added to control the rate of fermentation in bread dough. It also is used to strengthen the gluten (the elastic protein-water complex in certain doughs) and as a flavor enhancer, such as a topping on baked goods.

The food-processing category also contains grain mill products, which consist of milling flour and rice and manufacturing cereal breakfast food and blended or prepared flour.

In the "other food processing" category, salt is used mainly as a seasoning agent. Other food processing includes miscellaneous establishments that make food for human consumption (e.g., potato chips, pretzels) and for domestic pet consumption (e.g., cat and dog food).

Water Treatment.—Many areas of the United States have hard water, which contains excessive calcium and magnesium ions that contribute to the buildup of a scale or film of alkaline mineral deposits in household and industrial equipment. Commercial and residential water-softening units use salt to remove the ions causing the hardness. The sodium ions captured on a resin bed are exchanged for the calcium and magnesium ions. Periodically, the water-softening units must be recharged because the sodium ions become depleted. Salt is added and dissolved, and the brine replenishes the lost sodium ions.

Stocks

Because bulk salt is stored at many different locations, such as at the plants, warehouses, ports, and terminals, data on the quantity of salt stockpiled by the salt industry is not reliable enough to formulate accurate inventory totals; however, yearend stocks of producers were estimated to be 2 Mt, and consumer inventories also were estimated to be high. Most of these inventories were imported rock salt and solar salt. Many salt producers, States, municipalities, distributors, and road deicing contractors stockpiled additional quantities of salt in anticipation of adverse weather conditions. Deicing salt inventories were extremely large by yearend because the mild winter in the domestic snow belt did not require as much salt as had been stockpiled. For the reasons discussed above, salt stocks are assumed to be the difference between salt production and salt sold or used in calculating apparent consumption.

Transportation

Because the locations of the salt supplies are not often near consumers, transportation can become an important cost. Pumping salt brine through pipelines is an economic means of transportation but cannot be used for dry salt. Large bulk shipments of dry salt in ocean freighters or river barges are low in cost but are restricted in points of origin and consumption. River and lake movement of salt in winter is often severely curtailed because of frozen waterways. As salt is packaged, handled, and shipped in smaller units, the costs increase and are reflected in higher selling prices.

Transoceanic imports of salt have been increasing in some areas of the United States because they are less expensive with respect to transportation costs than that which could be purchased from domestic suppliers using rail transportation. Although shipping in larger vessels reduces shipping costs, transportation costs significantly add to the price of salt. In some cases, shipping costs are higher than the actual price of the salt. Another problem is that many ports are not deep enough to accommodate the larger ships.

Prices

The four types of salt that are produced have unique production, processing, and packaging factors that determine the selling prices. Generally, salt sold in bulk is less expensive than salt that has been packaged, pelletized, or pressed into blocks. Salt in brine is the least expensive salt sold because mining and processing costs are less. Vacuum pan salt is the most expensive because of the higher energy costs involved in processing and the purity of the product.

Price quotations are not synonymous with average values reported to the USGS. The quotations do not necessarily represent prices at which transactions actually took place or bid and asked prices. Yearend prices for salt are no longer quoted in Chemical Market Reporter; this information was last available for 1997. The average annual values, as collected by the USGS and listed in table 7, represent a national average value for each of the types of salt and the various product forms.

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Foreign Trade

Under Harmonized Tariff Schedule of the United States (HTS) nomenclature, imports are aggregated under one category named "Salt (including table and denatured salt) and pure sodium chloride, whether or not in aqueous solution, seawater." The same classification also applies to exports. The HTS code for salt is 2501.00.0000. The trade tables in this report list the previous and current identification codes for salt. Although several other HTS codes pertain to various salt classifications, the United States aggregates shipments under one code because the sums of individual subclassifications fail to meet the minimum dollar requirements necessary for individual listings.

Using The Journal of Commerce's Port Import Export Reporting Service (PIERS), which provides additional information on trade data on ocean commerce (no rail or truck traffic between the United States and Canada and Mexico is included) not available from other sources, the U.S. salt industry accounted for 38% of all U.S. salt imports in 2000. The three companies that imported salt were Cargill, IMC Salt, and Morton Salt Co.. Six salt distributors represented 41% of total imports, and the domestic chloralkali industry imported 9% of total salt. Therefore, the salt industry, salt distributors, and the chloralkali industry accounted for 88% of all salt imported in 2000. The majority of U.S. salt exports in 2000 was by five domestic salt producers: Cargill, Morton Salt, U.S. Salt, United Salt, and Western Salt, Inc. According to PIERS data, these five companies exported 84% of the total.

Based on U.S. Census Bureau data, in 2000, the United States exported 642,000 t; this was a 28% decrease compared with that of 1999 (table 8). Salt was shipped to 62 countries through 32 U.S. Customs districts; the Detroit, MI, district exported the most and represented 35% of the U.S. total (table 9). In 2000, the majority of exports, or 77% of the total, was to Canada.

Based on U.S. Census Bureau statistics, the United States imported 8.96 Mt of salt from 37 countries in 2000, which was slightly more than was imported during 1999 (table 10). Table 11 lists the imports of salt by Customs districts. The quantity of imported salt was about 14 times more than that of exports. This indicates the magnitude of the United States' reliance on salt imports. The majority of imported salt was brought into the country by foreign subsidiaries of major U.S. salt producers. Generally, imported salt can be purchased and delivered to many customers at a cost lower than the comparable domestic product because production costs are lower abroad, currency exchange rates are more favorable, and ocean freight rates are less expensive than overland rail or truck rates.

World Review

Table 12 lists world salt production statistics for 111 nations based on reported and estimated information. In 2000, total world production increased slightly compared with that of 1999. The United States remained the world's leading salt-producing country, representing 21% of total world output.

Most countries possess some form of salt production capability with production levels set to meet their own domestic demand requirements and with additional quantities available for export. Many developing nations tend to develop their agricultural resources to feed their population first. Development of easily extractable mineral resources follows, and salt is one of the first commodities to be mined. Some countries, such as the United States, import a substantial amount of salt to meet total demand requirements because of economic factors.

Australia.—Intense rain and floods from Cyclone Steve in March severely affected Dampier Salt Ltd.'s solar salt production ponds at Dampier and Lake MacLeod in the northwestern part of the country. Although the storm caused production to decline by about 15%, operations were back into full production later in the year (Industrial Minerals, 2000a)

Portugal.—VA Tech Ltd. of Switzerland and Uniteca S.A., a chloralkali producer in Portugal, formed a joint venture to construct a salt plant at Carrico. The plant, with production capacity of 170,000 t/yr, was scheduled to start up in late 2001. The majority of the salt will be used as feedstock for the chlorine facility, with the remainder sold to local markets. The salt will be solution-mined from an underground deposit and crystalized in surface evaporation ponds that will be heated by a natural gas-fired cogeneration plant (Industrial Minerals, 2000e).

Russia.—A solution mining project was scheduled to begin at Koverninsky District, Nizhegorodsky Oblast, where the Belbazh salt deposit with reserves of 711 Mt was discovered in 1973. The salt brine would provide feedstock to the local chloralkali facility. Although the plan was to mine about 1 million tons per year (Mt/yr), the initial output was scheduled to be between 80,000 t/yr to 100,000 t/yr (Industrial Minerals, 2000b). In addition, a new salt facility was commissioned by the joint stock company Silvinit at Solikamsk, Perm Oblast. The plant will produce 500,000 t/yr of technical-grade salt (Industrial Minerals, 2000c).

United Kingdom.—U.S. Salt Holdings L.L.C. of the United States acquired from Stavely Industries, plc, the vacuum pan salt operation operated by British Salt Ltd. The plant at Middlewich, Cheshire, had a capacity of 825,000 t/yr. The majority of salt sales were to the chemical, food processing, and water treatment industries. The only other vacuum pan operation in England was owned by Salt Union Inc., which was purchased by IMC Global, another U.S.-owned salt company, in 1999. IMC was the world's third largest salt producer with more than 15 Mt/yr of world salt capacity (Industrial Minerals, 2000d).

Vietnam.—Two new solar salt projects were announced at Quan The and Ninh Thuan. The domestic chemical industry anticipated that its demand for salt would increase to 1 Mt/yr by 2010 from its current level of 300,000 t/yr (Bertram, 2000).

Outlook

Supplies of salt are more than adequate to meet any surge in demand for the foreseeable future. The new rock salt mines in Michigan and New York that opened recently should increase domestic rock salt production and cause rock salt imports to decline. After a couple of mild winter seasons that reduced the demand for deicing salt, it is estimated that winter weather conditions will return to traditional precipitation patterns that will require greater quantities of rock salt. U.S. production of total salt for 2001 is estimated to be 47 Mt.

References Cited

Bertram, B.M., 2000, Salt: Mining Engineering, v. 52, no. 6, June, p. 57-60.
Chemical Market Reporter, 2000, IMC Global reports weak 2Q results; prospects dim for sale of salt biz: Chemical Market Reporter, v. 258, no. 7, August 14, p. 6.
Food and Nutrition Board, 1966, Sodium chloride, *in* Food chemicals codex

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(1st ed): Washington, DC, National Academy Press, p. 613-614.
Industrial Minerals, 2000a, Cyclone Steve disrupts Dampier salt: Industrial Minerals, no. 393, June, p. 9.
———2000b, Exploitation of Belbazh salt deposit to start: Industrial Minerals, no. 396, September, p. 28.
———2000c, Jt.St.Co. Silvinit commissions 0.5m tpa salt complex: Industrial Minerals, no. 393, June, p. 25.
———2000d, Stavely sells British Salt: Industrial Minerals, no. 394, July, p. 93.
———2000e, Wabag and Uniteca join forces in salt: Industrial Minerals, no. 396, September, p. 17.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Salt. Ch. in Mineral Commodity Summaries, annual.
Salt. Ch. in Minerals Yearbook, annual.

Other

The Chlorine Institute.
Handbook of World Salt Resources. S.J. Lefond, Plenum Press, 1969.
The Material Flow of Salt. U.S. Bureau of Mines Information Circular 9343, 1993.
Salt. Ch. in Canadian Minerals Yearbook, annual.
Salt. Ch. in Industrial Minerals and Rocks, Society of Mining, Metallurgy, and Exploration, Inc., 6th ed., Carr, D.D., ed., 1994.
Salt. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Salt Institute.
Salt. Mining Engineering, annual review of industrial minerals.
Sodium Chloride. American Chemical Society Monograph No. 145, Kaufmann, D.W., ed., Reinhold Publishing Corp., 1960.
Solution Mining Research Institute.

TABLE 1
SALIENT SALT STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Production: 2/	42,200	41,400	41,200	44,900	45,600
Brine	21,500	21,400	21,100	22,700	22,500
Rock	13,500	12,900	12,900	14,400	15,000
Solar	3,270	3,170	3,190	3,580	3,810
Vacuum and open pans	3,920	3,980	4,040	4,190	4,200
Sold or used by producers	42,900	40,600	40,800	44,400	43,300
Value	$1,060,000	$993,000	$986,000	$1,110,000	$1,040,000
Exports	869	748	731	892	642
Value	$39,300	$38,000	$35,200	$37,000	$37,800
Imports for consumption	10,600	9,160	8,770	8,870	8,960
Value	$167,000	$148,000	$145,000	$137,000	$127,000
Consumption, apparent 3/	52,600	49,000	48,800	52,400	51,600
Consumption, reported	52,800	49,500	44,200	50,000	54,000
World, production	204,000 r/	207,000 r/	200,000 r/	211,000 r/	214,000 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Excludes Puerto Rico.
3/ Sold or used plus imports minus exports.

TABLE 2
SALT PRODUCED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM 1/

(Thousand metric tons)

Product form	Vacuum and open pans	Solar	Rock	Brine	Total
1999:					
Bulk	816	1,910	13,800	22,700	39,300
Compressed pellets	1,270	346	XX	XX	1,620
Packaged	1,900	1,160	549	XX	3,610
Pressed blocks	208	159	72	XX	439
Total	4,190	3,580	14,400	22,700	44,900
2000:					
Bulk	773	2,000	14,600	22,500	39,900
Compressed pellets	1,270	359	XX	XX	1,630
Packaged	1,960	1,300	390	XX	3,640
Pressed blocks	207	152	67	XX	426
Total	4,200	3,810	15,000	22,500	45,600

XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 3
SALT SOLD OR USED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM 1/ 2/

(Thousand metric tons and thousand dollars)

Product form	Vacuum and open pans		Solar		Rock		Brine		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1999:										
Bulk	816	38,000	1,410	38,200	14,100	294,000	22,700	151,000	39,000	521,000
Compressed pellets	1,270	162,000	299	33,300	XX	XX	XX	XX	1,570	196,000
Packaged:										
Less-than-5-pound units	232	NA	3	NA	1	NA	XX	XX	236	XX
More-than-5-pound units	1,650	NA	954	NA	576	NA	XX	XX	3,180	XX
Total	1,890	247,000	957	67,100	577	36,100	XX	XX	3,420	350,000
Pressed blocks:										
For livestock	88	NA	118	NA	68	NA	XX	XX	274	XX
For water treatment	120	NA	8	NA	6	NA	XX	XX	134	XX
Total	209	19,000	126	11,800	73	7,280	XX	XX	408	38,100
Grand total	4,190	466,000	2,790	150,000	14,700	337,000	22,700	151,000	44,400	1,110,000
2000:										
Bulk	773	39,100	1,440	30,500	13,100	252,000	22,500	128,000	37,800	450,000
Compressed pellets	1,260	166,000	320	35,900	XX	XX	XX	XX	1,580	202,000
Packaged:										
Less-than-5-pound units	234	NA	4	NA	1	NA	XX	XX	239	XX
More-than-5-pound units	1,710	NA	1,060	NA	434	NA	XX	XX	3,210	XX
Total	1,950	249,000	1,070	76,200	435	27,100	XX	XX	3,450	353,000
Pressed blocks:										
For livestock	86	NA	119	NA	75	NA	XX	XX	280	XX
For water treatment	120	NA	7	NA	6	NA	XX	XX	133	XX
Total	207	20,900	126	11,800	81	7,360	XX	XX	414	40,100
Grand total	4,190	475,000	2,950	154,000	13,600	286,000	22,500	128,000	43,300	1,040,000

NA Not available. XX Not applicable.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ As reported at salt production locations, the term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company. Because data do not include salt imported, purchased, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 5 and 6, which are derived from company totals.

TABLE 4
SALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1999		2000	
	Quantity	Value	Quantity	Value
Kansas	2,780	115,000	2,770	114,000
Louisiana	16,500	193,000	13,400	124,000
New York	4,220	209,000	5,440	218,000
Texas	10,200	97,500	10,800	104,000
Utah	1,890	92,000	2,110	108,000
Other Eastern States 3/	7,610	323,000	7,480	311,000
Other Western States 4/	1,210	75,800	1,240	64,500
Total	44,400	1,110,000	43,300	1,040,000
Puerto Rico e/	45	1,500	45	1,500

e/ Estimated.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company.

3/ Includes Alabama, Michigan, Ohio, Tennessee, and West Virginia.

4/ Includes Arizona, California, Nevada, New Mexico, and Oklahoma.

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TABLE 5
DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES, BY END USE AND TYPE 1/ 2/

(Thousand metric tons)

End use	Standard industrial classification	Vacuum and open pans		Solar		Rock		Brine		Grand total 3/	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Chemical:											
Chloralkali producers	2812	33	31	374	442	841	230	20,200	20,600	21,400	21,300
Other chemical	28 (excludes 2812, 2899)	255	257	233	168	392	654	115	2	996	1,080
Total		288	288	608	610	1,230	885	20,300	20,600	22,400	22,400
Food-processing industry:											
Meat packers	201	268	268	50	54	87	81	--	--	405	402
Dairy	202	119	120	6	7	2	2	--	--	127	129
Canning	2091, 203	149	149	43	40	32	30	(4/)	(4/)	225	220
Baking	205	213	214	7	7	15	13	--	--	234	234
Grain mill products	204 (excludes 2047)	95	93	6	11	21	30	--	--	121	133
Other food processing	206-208, 2047, 2099	448	505	70	84	49	47	2	1	569	638
Total		1,290	1,350	181	202	206	203	2	2	1,680	1,760
General industrial:											
Textiles and dyeing	22	158	138	55	52	14	11	9	8	235	209
Metal processing	33, 34, 35, 37	8	6	14	24	131	82	(4/)	--	153	112
Rubber	2822, 30 (excludes 3079)	4	3	1	1	1	1	66	66	72	71
Oil	13, 29	27	28	174	186	42	49	2,190	2,250	2,430	2,510
Pulp and paper	26	15	16	48	45	30	26	19	19	112	106
Tanning and leather	311	21	16	32	30	50	36	--	--	103	82
Othe industrial	--	99	89	46	50	54	62	(4/)	(4/)	199	202
Total		331	295	370	388	322	268	2,280	2,340	3,300	3,290
Agricultural:											
Feed retailers and dealers mixers	5159	349	385	383	385	478	469	--	--	1,210	1,240
Feed manufacturers	2048	60	55	121	126	353	359	--	--	533	540
Direct-buying end user	02	5	5	19	20	63	63	--	--	87	88
Total		413	445	523	531	894	891	--	--	1,830	1,870
Water treatment:											
Government (Federal, State, local)	2899	17	17	95	82	315	128	4	4	431	231
Commercial or other	2899	129	142	217	184	119	30	2	3	468	358
Total		147	159	312	266	434	157	6	6	899	589
Ice control and stabilization:											
Government (Federal, State, local)	9621	1	2	594	515	12,900	16,900	(4/)	--	13,500	17,400
Commercial or other	--	6	7	53	122	1,760	2,240	--	--	1,820	2,370
Total		7	10	647	637	14,600	19,100	(4/)	--	15,300	19,700
Distributors:											
Agricultural distribution	5191	90	90	116	121	48	51	(4/)	--	254	262
Grocery wholesalers and retailers	514, 54	529	528	242	238	60	56	--	--	831	823
Institutional wholesalers and end users	58, 70	171	113	50	47	41	45	(4/)	(4/)	263	206
Water-conditioning distribution	7399	163	152	410	391	27	24	--	--	600	568
U.S. Government resale	9199	(4/)	(4/)	1	1	1	1	--	--	2	2
Other wholesalers and retailers	5251	774	796	737	755	404	401	(4/)	(4/)	1,920	1,950
Total		1,730	1,680	1,560	1,550	582	578	(4/)	1	3,870	3,810
Other 5/		116	105	54	65	394	341	96	58	663	570
Grand total		4,320	4,330	4,250	4,250	18,700	22,400	22,700	23,000	50,000	54,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The quality of imports included in the total for each type of salt is the amount reported by the U.S. salt industry, not the quantity reported by the U.S. Census Bureau that appears in tables 1, 11, and 12.

3/ Because data include salt imported, produced, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 1, 3, and 4, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 6 because of changes in inventory and incomplete data reporting.

4/ Less than 1/2 unit.

5/ Includes exports.

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TABLE 6
DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT IN THE UNITED STATE, BY DESTINATION 1/ 2

(Thousand metric tons)

Destination	1999				2000			
	Evaporated				Evaporated			
	Vacuum and open pans	Solar	Rock	Total	Vacuum and open pans	Solar	Rock	Total
Alabama	70	1	78	149	71	2	73	146
Alaska	2	5	(3/)	7	3	4	(3/)	7
Arizona	13	93	1	107	12	95	1	109
Arkansas	49	2	55	106	48	2	59	109
California	185	647	2	835	196	670	3	868
Colorado	16	79	107	202	13	82	133	228
Connecticut	14	134	77	224	15	119	176	310
Delaware	4	12	3	19	4	11	3	18
District of Columbia	1	1	20	21	1	1	21	23
Florida	70	190	8	268	74	206	7	288
Georgia	94	100	54	248	95	55	63	212
Hawaii	1	3	(3/)	3	(3/)	1	(3/)	2
Idaho	16	74	39	129	16	98	5	119
Illinois	338	127	1,890	2,360	343	120	2,320	2,780
Indiana	241	118	714	1,070	251	112	844	1,210
Iowa	161	74	473	708	152	89	533	774
Kansas	93	41	722	856	93	44	592	728
Kentucky	64	6	437	507	64	5	542	610
Louisiana	59	1	536	597	57	1	565	623
Maine	13	7	163	182	14	6	185	205
Maryland	63	61	175	298	64	82	161	307
Massachusetts	37	152	208	398	32	22	333	387
Michigan	302	36	1,720	2,050	308	38	2,180	2,520
Minnesota	143	193	523	859	138	203	624	965
Mississippi	36	(3/)	213	249	32	(3/)	250	282
Missouri	133	35	587	755	131	44	382	557
Montana	1	34	1	36	1	36	2	39
Nebraska	78	44	163	285	79	46	171	297
Nevada	3	262	15	280	3	276	12	290
New Hampshire	11	32	173	217	13	28	131	172
New Jersey	110	63	51	224	108	69	134	311
New Mexico	11	76	2	89	15	71	(3/)	87
New York	259	78	2,430	2,770	271	77	3,280	3,630
North Carolina	126	89	74	289	108	177	82	367
North Dakota	7	23	10	41	7	19	7	32
Ohio	413	58	2,220	2,700	415	56	3,330	3,800
Oklahoma	41	19	98	157	39	19	63	121
Oregon	21	145	1	167	19	137	2	157
Pennsylvania	181	107	1,490	1,780	173	104	1,840	2,110
Rhode Island	7	70	41	118	7	2	125	134
South Carolina	32	11	6	50	33	13	5	51
South Dakota	24	53	40	117	23	48	40	111
Tennessee	110	5	490	605	110	6	403	520
Texas	206	125	182	513	212	126	189	528
Utah	9	336	96	442	9	414	(3/)	423
Vermont	6	2	275	284	6	7	335	348
Virginia	83	71	278	432	75	81	147	303
Washington	23	171	2	196	22	124	3	149
West Virginia	15	5	225	245	15	5	204	223
Wisconsin	217	125	1,240	1,580	222	129	1,570	1,920
Wyoming	(3/)	23	1	25	(3/)	24	2	26
Other 4/	107	31	291	428	117	48	295	460
Total 5/	4,320	4,250	18,700	27,300	4,330	4,250	22,400	31,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Each salt type includes domestic and imported quantities. Brine is excluded because brine is not shipped out of State.

3/ Less than 1/2 unit.

4/ Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, and some shipments to upspecified destinations.

5/ Because data include salt imported, purchased, and/or sold from inventory from regional distribution centers, evaporated and rock salt distributed by State may differ from totals shown in tables 1 and 3, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 5 because of changes in inventory and/or incomplete data reporting.

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TABLE 7
AVERAGE VALUE OF SALT, BY PRODUCT FORM AND TYPE 1/

(Dollars per metric ton)

Product form	Vacuum and open pans	Solar	Rock	Brine
1999:				
Bulk	46.56	27.17	20.91	6.65
Compressed pellets	127.49	111.36	XX	XX
Packaged	130.88	70.15	62.60	XX
Average 2/	112.49	52.08	22.55	6.65
Pressed blocks	91.16	93.59	99.19	XX
2000:				
Bulk	50.58	21.16	19.28	5.70
Compressed pellets	130.97	112.28	XX	XX
Packaged	128.05	71.56	62.34	XX
Average 2/	113.95	50.46	20.67	5.70
Pressed blocks	101.18	93.52	91.14	XX

XX Not applicable.
1/ Net selling value, free on board plant, excluding container costs.
2/ Salt value data previously reported were an aggregate value per ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented that is based on the aggregate values and quantities of the product form for each type of salt shown in table 3.

TABLE 8
U.S. EXPORTS OF SALT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Bahamas, The	(3/)	122	2	222
Bahrain	1	191	1	221
Canada	730	23,200	500	22,800
Chile	(3/)	58	1	84
China	2	345	(3/)	447
Colombia	1	214	2	413
Costa Rica	1	74	(3/)	67
El Salvador	1	192	1	175
Haiti	(3/)	65	5	1,370
Honduras	4	370	4	469
Hong Kong	1	139	(3/)	78
Israel	1	66	(3/)	6
Italy	2	66	(3/)	50
Japan	4	584	3	575
Korea, Republic of	(3/)	96	1	55
Malaysia	1	232	(3/)	48
Mexico	83	4,760	82	5,270
Netherlands	1	49	(3/)	159
Nicaragua	(3/)	10	1	91
Norway	1	36	(3/)	4
Panama	27	711	1	156
Saudi Arabia	10	883	11	1,360
Singapore	2	113	13	490
Taiwan	3	752	3	269
United Arab Emirates	(3/)	185	1	319
United Kingdom	10	836	3	617
Venezuela	1	655	2	346
Other	5	1,970 r/	5	1,610
Total	892	37,000	642	37,800

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Free alongside ship value at U.S. ports.
3/ Less than 1/2 unit; included with "Other."

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF SALT, BY CUSTOMS DISTRICT 1/

(Thousand metric tons and thousand dollars)

District	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Baltimore, MD	2	169	(3/)	36
Boston, MA	(3/)	14	--	--
Buffalo, NY	25	2,870	27	2,970
Charleston, SC	2	321	1	56
Chicago, IL	(3/)	92	45	1,310
Cleveland, OH	209	3,700	2	255
Detroit, MI	347	8,530	226	7,060
Duluth, MN	(3/)	3	(3/)	14
El Paso, TX	2	121	2	116
Great Falls, MT	6	265	17	1,450
Honolulu, HI	(3/)	5	--	--
Houston, TX	12	2,000	14	2,400
Laredo, TX	74	4,040	73	4,500
Los Angeles, CA	8	2,100	17	1,640
Miami, FL	2	381	4	539
Mobile, AL	1	78	1	82
New Orleans, LA	30	1,110	4	637
New York, NY	8	705	4	1,100
Nogales, AZ	3	99	3	158
Norfolk, VA	2	419	2	480
Ogdensburg, NY	25	657	4	370
Pembina, ND	6	532	17	1,290
Philadelphia, PA	(3/)	407	(3/)	123
Port Arthur, TX	(3/)	33	6	1,580
Portland, ME	(3/)	25	2	127
St. Albans, VT	1	64	4	30
St. Louis, MO	(3/)	10	12	79
San Diego, CA	4	491	(3/)	494
San Francisco, CA	12	687	(3/)	538
San Juan, PR	(3/)	18	(3/)	12
Savannah, GA	(3/)	294	(3/)	206
Seattle, WA	13	490	31	969
Tampa, FL	(3/)	73	(3/)	35
Wilmington, NC	--	--	(3/)	23
Other 4/	98	6150	123	7080
Total	892	37,000	642	37,800

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Free alongside ship value at U.S. ports.

3/ Less than 1/2 unit.

4/ Unknown but assumed to be rail and/or truck shipments to Canada through various points of departure.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF SALT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Australia	27	617	(3/)	6
Bahamas, The	946	10,400	858	9,770
Bahrain	5	59	--	--
Bosnia and Herzegovina	26	411	--	--
Brazil	101	940	217	2,290
Canada	3,810	66,400	3,470	58,000
Chile	1,660	20,600	2,050	19,500
China	1	715	(3/)	695
Dominican Republic	32	403	167	1,790

See footnotes at end of table.

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TABLE 10--Continued
U.S. IMPORTS FOR CONSUMPTION OF SALT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Egypt	143	1,100	313	2,500
France	5	1,240	6	1,370
Germany	1	681	10	983
Ireland	50	347	42	295
Israel	(3/)	144	1	455
Italy	15	261	2	353
Japan	1	167	1	149
Korea, Republic of	1	579	1	679
Mexico	1,250	19,300	1,180	17,900
Namibia	12	184	17	283
Netherlands	113	3,760	187	4,460
Netherlands Antilles	101	1,690	132	2,190
Peru	538	4,280	291	2,260
Spain	2	40	(3/)	106
Sweden	2	1,760	(3/)	139
United Kingdom	8	163	15	187
Venezuela	18	148	--	--
Other	3	389	(3/)	385
Total	8,870	137,000	8,960	127,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value only.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS OF SALT, BY CUSTOMS DISTRICT 1/

(Thousand metric tons and thousand dollars)

District	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Anchorage, AK	8	186	14	398
Baltimore, MD	723	10,500	766	11,600
Boston, MA	669	6,930	703	6,480
Buffalo, NY	499	9,110	344	7,050
Charleston, SC	142	3,520	179	3,630
Chicago, IL	615	10,900	391	5,380
Cleveland, OH	271	5,920	154	2,470
Columbia-Snake, OR	247	3,420	280	3,580
Dallas-Fort Worth, TX	(3/)	110	(3/)	53
Detroit, MI	795	15,800	824	14,900
Duluth, MN	77	885	146	1,950
El Paso, TX	1	179	(3/)	99
Great Falls, MT	(3/)	26	(3/)	35
Houston-Galveston, TX	(3/)	165	1	256
Laredo, TX	1	159	1	241
Los Angeles, CA	94	2,080	114	2,640
Miami, FL	(3/)	128	1	380
Milwaukee, WI	930	16,200	808	16,300
Minneapolis, MN	(3/)	18	(3/)	3
Mobile, AL	(3/)	14	(3/)	4
New Orleans, LA	214	2,930	32	459
New York, NY	703	9,150	1,400	15,400
Nogales, AZ	(3/)	6	(3/)	78
Norfolk, VA	114	1,180	227	2,570
Ogdensburg, NY	143	2,890	138	2,910
Pembina, ND	3	289	1	101
Philadelphia, PA	539	6,920	705	7,850
Portland, ME	915	10,600	510	4,880

See footnotes at end of table.

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TABLE 11--Continued
U.S. IMPORTS OF SALT, BY CUSTOM DISTRICTS 1/

(Thousand metric tons and thousand dollars)

District	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Providence, RI	393	4,220	358	3,290
St. Albans, VT	8	839	3	294
St. Louis, MO	(3/)	15	(3/)	10
San Diego, CA	1	72	(3/)	22
San Francisco, CA	(3/)	110	(3/)	120
San Juan, PR	8	207	8	156
Savannah, GA	78	1,080	62	1,030
Seattle, WA	342	5,200	297	4,150
Tampa, FL	261	3,460	305	4,130
Washington, DC	(3/)	3	--	--
Wilmington, NC	73	1,430	179	1,960
Total	8,870	137,000	8,960	127,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Customs value only.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 12
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
Afghanistan (rock salt) e/	13	13	13	13	13
Albania e/	10	10	10	10	10
Algeria (brine and sea salt)	178	137	172	164 r/ 4/	165
Angola e/	30	30	30	30	30
Argentina:					
Rock salt	--	(5/)	(5/) e/	(5/)	(5/)
Other salt	1,096	841	850 e/	1,263 r/ 4/	1,000
Total	1,096	841	850 e/	1,263 r/ 4/	1,000
Armenia	26	26 e/	25	27 4/	30 4/
Australia (brine salt and marine salt)	7,905	8,801	8,879	10,003 4/	8,798 4/
Austria: e/					
Brine salt	367	400	500	400	400
Rock salt	1	1	1	1	1
Total	368	401	501	401	401
Azerbaijan	3 e/	3	6	6	6
Bahamas, The e/	900	900	900	900	900
Bangladesh (marine salt) e/ 6/	350	350	350	350	350
Belarus	231 r/	297 r/	355 r/	400 r/	400
Benin (marine salt) e/	(5/)	--	--	15 r/	15
Bolivia	(5/)	1	5	1 r/ 4/	(5/) 4/
Bosnia and Herzegovina e/	50	50	50	50	50
Botswana 7/	94	185	215	233 r/ 4/	185 4/
Brazil:					
Brine salt	3,870	5,064	5,353	4,528 r/ 4/	4,500
Rock salt	1,514	1,452	1,484	1,430 r/ 4/	1,500
Total	5,384	6,516	6,837	5,958 r/ 4/	6,000
Bulgaria	1,600	1,600	2,400	2,500	2,500
Burkina Faso e/	7	5	5	5	5
Burma e/ 8/	35	35	35	35	35
Cambodia e/	40	40	40	40	40
Canada	12,248	13,264	13,296	12,686 r/ 4/	11,935 4/
Cape Verde e/	5	6	7	2 r/	2
Chile	4,043	5,488	6,207	6,074 r/ 4/	6,000
China	29,035	30,830	22,420	28,124 4/	31,280 4/

See footnotes at end of table.

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TABLE 12--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
Colombia:					
Marine salt	153	142 r/	166 r/	157 r/ 4/	160
Rock salt	424	232	330	304 r/ 4/	300
Total	576 r/	374 r/	496 r/	461 r/ 4/	460
Costa Rica (marine salt) e/	37	37	37	37	37
Croatia	19	17	31	18 4/	20
Cuba e/	180	180	180	180	180
Denmark (sales) e/	600	600	600	600	605
Dominican Republic: e/					
Marine salt	50 4/	50	50	50	50
Rock salt	11 4/	12	12	12	12 4/
Total	61 4/	62	62	62	62 4/
Ecuador e/	110	100	100	95	90
Egypt	1,530	2,024 r/	2,387 r/	2,400	2,400
El Salvador (marine salt) e/	31	95 r/	89 r/ 4/	90	90
Eritrea:					
Marine salt	198	252	114	114 r/	100
Rock salt e/	2	--	--	--	--
Total	200	252	114	114 r/	100
Ethiopia (rock salt) e/ 6/	5	1	1	1	1
France:					
Brine salt	1,460	1,475	1,500 e/	1,500	1,500
Marine salt	1,970	1,188	1,200 e/	1,200	1,200
Rock salt e/	160	371 4/	300	300	300
Salt in solution	4,273	4,051	4,000 e/	4,000	4,000
Total	7,860 e/	7,085	7,000 e/	7,000	7,000
Germany:					
Marine salt e/	731 4/	700	700	700	700
Rock salt and other	15,176	15,087	15,000 e/	15,000	15,000
Total	15,907	15,787	15,700 e/	15,700	15,700
Ghana e/	50	50	50	50	50
Greece	147	150	150 e/	150	150
Guadeloupe e/	200	200	200	200	200
Guatemala e/	48	48	48	50	49
Guinea	--	--	--	15	15
Honduras e/	25	25	25	25	25
Iceland e/	4	4	4	4	4
India:					
Marine salt	14,464	14,249	11,962	14,450 4/	14,450
Rock salt	2 4/	3	2	3	3
Total	14,466	14,251	11,964	14,453 4/	14,453
Indonesia e/	670	680	650	680	680
Iran 9/	1,000 e/	1,180	1,912 r/	1,600 r/ 4/	1,600
Iraq e/	250	250	250	300	300
Israel	765 r/	750 r/	874 r/	883 r/	863
Italy:					
Brine salt and rock salt	2,941	2,910	3,000 e/	3,000	3,000
Marine salt, crude e/ 10/	600	600	600	600	600
Total	3,541	3,510	3,600 e/	3,600	3,600
Jamaica	18	16	16	15	15
Japan	1,344 r/	1,329 r/	1,293 r/	1,327 r/ 4/	1,300
Jordan	50 r/	158 r/	263 r/	393 r/	546
Kenya (crude salt)	41	6 4/	22	45 r/ 4/	45
Korea, North e/	590	590	550	500	500
Korea, Republic of e/	770	770	780	800	800
Kuwait e/	100	100	100	100	100
Laos (rock salt) e/	14	18	39 4/	40	40
Lebanon e/	4	4	4	4	4
Leeward and Windward Islands e/	1	1	--	--	--
Libya e/	30	30	30	30	40

See footnotes at end of table.

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TABLE 12--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
Madagascar	42 r/	37 r/	27	25	25
Mali e/	6	5	6	6	6
Malta (marine salt) e/	(5/)	(5/)	(5/)	(5/)	(5/)
Martinique e/	200	200	200	200	200
Mauritania e/	6	6	6	6	6
Mauritius e/	7 r/	6	6	6	6
Mexico	8,508	7,933	8,412	8,236 r/ 4/	8,884
Mongolia (mine output)	1	1	1 e/	1	1
Morocco (marine salt and rock salt)	171	258	148	150	150
Mozambique (marine salt) e/	60	60	60	60	60
Namibia (marine salt)	356	493	507 r/	503 r/ 4/	510
Nepal e/ 11/	7	7	6	6	6
Netherlands e/	5,530 4/	5,000	5,500 4/	5,000	5,000
Netherlands Antilles	366	432	487	500	500
New Zealand e/	67	67	65	65	60
Nicaragua (marine salt) e/	15	14 4/	15 4/	15	15
Niger e/	3	3	2	2	2
Pakistan: 6/					
Marine salt	18 e/	19	15	16 4/	20
Rock salt	940 e/	1,042	1,038	1,019 4/	1,313 4/
Total	958 e/	1,061	1,053	1,035 4/	1,333
Panama (marine salt) e/	22	22	23	23	23
Peru	293	79	80 e/	80	80
Philippines (marine salt)	619 r/	687 r/	728 r/	704 r/ 4/	705
Poland:					
Rock salt	923	791	748	923 r/ 4/	900
Other salt	3,240	3,070	3,257	3,289 r/ 4/	3,300
Total	4,163	3,859	4,005	4,212 r/ 4/	4,200
Portugal (rock salt) e/	610 4/	600	600	600	600
Romania:					
Rock salt	350	350 e/	68	70	70
Other salt	2,339	2,300 e/	2,152	2,000	2,000
Total	2,689	2,650 e/	2,220	2,070	2,070
Russia	2,100	2,100	2,200 r/	3,200 r/ 4/	3,200
Senegal e/	120	120	130	350 r/ 4/	350
Serbia and Montenegro	22	28	78	64 r/ 4/	78
Sierra Leone e/	50	10	--	--	--
Slovakia	107	101	100 e/	99 r/ 4/	100
Slovenia e/	5	5	5	5	2
Somalia e/	1	1	1	1	1
Saudi Arabia e/	140	140	140	140	140
South Africa	253	322	356	365 4/	346 4/
Spain: e/					
Marine salt and other evaporated salt	1,500	1,500	1,500	1,200	1,200
Rock salt	2,500	2,500	2,000	2,000	2,000
Total	4,000	4,000	3,500	3,200	3,200
Sri Lanka e/	65	65	82 r/ 4/	97 r/ 4/	96
Sudan e/	50	50	45	50	50
Switzerland e/	300	300	300	300	300
Syria	72	70 e/	163	150	150
Taiwan (marine salt)	233	62	7	77 r/ 4/	80
Tanzania	87	73 r/	75 r/ e/	36 r/	36
Thailand:					
Rock salt	530	555	546	740 r/ 4/	792 4/
Other e/	100	100	100	100	100
Total	630	655	646	840 r/ 4/	892 4/
Tunisia (marine salt)	478	394	473	447 r/	481 4/
Turkey	2,068	2,344	2,170	2,200	2,200
Turkmenistan	256	217	215 e/	215	215
Uganda e/	10	10	5	5	5
Ukraine e/	2,800	2,500	2,500	2,185 r/ 4/	2,287 4/

See footnotes at end of table.

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TABLE 12--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999 e/	2000 e/
United Kingdom: e/					
Brine salt 12/	1,300	1,300	1,300	1,300	1,300
Rock salt	1,800	1,800	1,800	1,500	1,500
Other salt 12/	3,510	3,500	3,500	3,000	3,000
Total	6,610	6,600	6,600	5,800	5,800
United States, including Puerto Rico:					
United States:					
Brine	21,500	21,400	21,100	22,700 4/	22,500 4/
Rock salt	13,500	12,900	12,900 r/	14,400 4/	15,000 4/
Solar salt	3,270	3,170	3,190	3,580 4/	3,810 4/
Vacuum pan and open pan	3,920	3,980	4,040	4,190 4/	4,200 4/
Puerto Rico e/	45	45	45	45	45
Total e/	42,300	41,500	41,300	45,000	45,600 4/
Venezuela e/	350	350	350	350	350
Vietnam	709 r/	743 r/	717 r/	720 r/	730
Yemen e/	135	146	147	147	150
Grand total	204,000 r/	207,000 r/	200,000 r/	211,000 r/	214,000

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 10, 2001.

3/ Salt is produced in many other countries, but quantities are relatively insignificant, and reliable production data are not available. Some salt brine production data for manufacture of chlorine, caustic soda, and soda ash are not reported because of incomplete data reporting by many countries.

4/ Reported figure.

5/ Less than 1/2 unit.

6/ Year ending June 30 of that stated.

7/ From natural soda ash production.

8/ Brine salt is produced as reported by the Burmese Government in metric tons, was as follows: 1996--71,350; 1997--97,276; 1998--91,992; 1999-- 61,674; and 2000--69,245.

9/ Year beginning March 21 of that stated.

10/ Does not include production from Sardinia and Sicily, estimated to be 200,000 metric tons per year.

11/ Year ending July 15 of that stated.

12/ Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brine; that captioned "Other salt" is the salt content of brines used for purposes other than production of salt.

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SAND AND GRAVEL, CONSTRUCTION

By Wallace P. Bolen

Domestic survey data and tables were prepared by Cheryl J. Crawford, statistical assistant.

Construction sand and gravel, one of the most accessible natural resources and a major basic raw material, is used mostly by the construction industry. The construction sand and gravel industry is a major contributor to and an indicator of the economic well-being of the Nation, producing a high volume of basic products with low unit value.

A total of 1.12 billion metric tons (Gt) of construction sand and gravel was produced in the United States in 2000; this was a slight increase compared with that of 1999 (table 1). After a decrease in production in 1991, sand and gravel production increased each year for the following 9 years, an indication of the continuous strong demand for construction aggregates in the United States.

In January 2001, the U.S. Geological Survey (USGS) mailed 7,892 construction sand and gravel survey forms to operations throughout the United States; an additional 372 operations that were not mailed survey forms provided information to the USGS. In 2000, 6,204 operations were active, 1,175 operations were idle, and 885 operations were either reported or assumed to be permanently shut down. A small number of the idle sand and gravel operations reported the recycling of asphalt and portland cement concrete but no sand and gravel mining. In 2000, of the 6,204 active operations surveyed, 4,272, or 68.9%, responded to the USGS survey. These operations contributed 78.2% of the 1.12 Gt produced in 2000. The 6,204 operations were run by 3,901 companies with 8,224 active sand and gravel pits (tables 9, 10).

Foreign trade of construction sand and gravel remained minor in 2000. Exports increased by about 46% to 2.41 million metric tons (Mt), but the value decreased by 13% to $24.2 million when compared with the 1999 results.

Imports increased by nearly 50% to 2.87 Mt, and their value increased by about 36% to $33.3 million. Because imports and exports were small, domestic apparent consumption of construction sand and gravel, defined as production for consumption (sold or used) plus total imports minus total exports, was essentially equal to the U.S. production of 1.12 Gt.

Legislation and Government Programs

On March 9, the U.S. Army Corps of Engineers published in the Federal Register the new nationwide permit (NWP) program that took effect June 7. The new general conditions in the NWP program affects the use of NWPs in "designated critical resource waters" and in "waters of the U.S." within 100-year floodplains. The Corps modified nine general conditions to the rule; three of these are of particular interest to the sand and gravel industry. The first condition concerns water quality and requires producers seeking NWPs to provide water quality management plans. The second concerns the management of water flows and requires activities to be designed to maintain preconstruction downstream flow conditions. Lastly, the amended general condition on mitigation requires a minimum 1:1 replacement ratio for all wetlands affected and also includes

Construction Sand and Gravel in the 20th Century

In 1900, construction sand and gravel consumption in the United States was probably about 19 million metric tons, but published statistics did not begin until 1905, when the U.S. Geological Survey reported production of about 21 million tons valued at $11.2 million. The average value was $0.53 per ton but ranged from $0.05 to $6.60 per ton. This included sand for such industrial uses as abrasive, foundry, and glassmaking sands. In 1905, production of building sand was reported to be about 9 million tons valued at $4.3 million. These sands included those used for mortar and plaster and sand used as aggregate in making concrete structures. The demand for concrete structures had increased at about the turn of the century. New York, Pennsylvania, Missouri, Indiana, and Ohio were the largest producing States in 1905, and much of the sand came from dredging the Delaware, Mississippi, Ohio, Potomac, and Tennessee Rivers and the Great Lakes. Gravel consumed in 1905 was about 4.9 million tons valued at $1.8 million and was used in concrete, roadmaking, and roofing. The average price for gravel for roofing purposes was $0.75 to $1.00 per ton.

In 2000, construction sand and gravel production was 1.12 billion tons, about 59 times the amount sold and used in 1900. Production of sand and gravel, especially from dredges in the rivers and lakes of the Eastern United States, had been mostly replaced by crushed stone operations and, to a lesser extent, sand and gravel open pits. Most sand and gravel production came from land sources. In 2000, only 12% of all operations were dredging operations, including dredges that worked in man-made lakes. The majority of sand and gravel was produced west of the Mississippi River, but Michigan and Ohio did remain among the top five States in sand and gravel production. Every State produced sand and gravel in 2000, and the largest producing State, California, produced more than seven times what the entire country produced in 1905. The average value of sand and gravel in 2000 was $4.81 per ton and ranged from $3.09 per ton for fill to about $12.35 per ton for roofing granules. The constant dollar average price of sand and gravel, which is the actual price adjusted for inflation, had not increased significantly since 1900 mostly owing to vast improvements in equipment and technologies that resulted in much greater efficiencies and productivity. More than half of the sand and gravel consumed in 2000 was used in road-related construction.

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open waters in its coverage area (Aggregates Manager, 2000c).

The National Institute for Occupational Safety and Health has identified noise-induced hearing loss as 1 of the 10 leading work-related diseases and injuries in mining. Hearing loss can cause safety problems in the workplace, as well as diminish the quality of life. The loudness and the duration of noise exposure are both factors in causing hearing loss.

The Mine Safety and Health Administration's (MSHA) new rules on noise exposure went into effect September 13. The new MSHA noise rules require mine operators for the first time to enroll miners in a hearing protection program if they are exposed to an average sound level of 85 decibels or more over an 8-hour period. The program will include training, hearing tests, and providing protectors, such as ear plugs. Training will cover the dangers of noise exposure and the benefits of using protectors and how to use them. Mine operators must offer miners testing and hearing protectors, but the use of hearing protectors at that noise level will be voluntary, as will the hearing tests. (Mine Safety and Health Administration, 1999).

Production

Of the four major geographic regions, the West again led the Nation in the production of construction sand and gravel with 436 Mt, or 39% of the U.S. total (table 2). It was followed by the Midwest with 333 Mt, or 29%; the South with 244 Mt, or 22%; and the Northeast with 109 Mt, or 10%. Production increased slightly in all the major geographic regions compared with that of 1999.

Of the nine geographic divisions, the East North Central led the Nation in the production of construction sand and gravel with 225 Mt, or 20% of the U.S. total, and was followed by the Pacific and Mountain, each with 218 Mt, or 19.5% (table 2; figure 1). Production increased in five of the nine divisions compared with that of 1999—New England, 8.2%; the South Atlantic, 4.3%; the Mountain, 2.3%; the East North Central, 1.8%; and the Pacific, 1.4%. Production decreased in the East South Central, 1.9%; the West North Central, 1.8%; and the Middle Atlantic, 1.5%. Production in the West South Central was unchanged compared with that of 1999.

A review of the production for consumption by size of operation indicates that 35.8% of the construction sand and gravel produced in 2000 came from 1,939 operations reporting between 100,000 and 499,999 metric tons per year (t/yr), 25.2% came from 450 operations reporting between 500,000 and 999,999 t/yr, and 28.7% came from 208 operations reporting more than 1 million metric tons per year (Mt/yr) (table 8).

Hundreds of operations are idled, closed, or abandoned each year, and a similar number are reactivated or opened each year. The changing location of construction and highway projects each year is the major stimulus in decisions to open, idle, or close operations.

The estimated production for consumption by quarter in 2000 indicates that 30% of the construction sand and gravel in the United States was produced in the third quarter, followed by the second and the fourth quarters (table 3). Estimated production by each quarter was also available for most States (table 5).

In 2000, construction sand and gravel was produced in every State (table 4). The leading States, in descending order of tonnage, were California, Texas, Michigan, Arizona, Ohio, Colorado, Washington, Wisconsin, Minnesota, and Nevada. Their combined production represented 55% of the national total. Production increased in 24 States and decreased in 26 States compared with that of 1999. Production increased in 7 of the top 10 States; decreases occurred in Colorado, Ohio, and Washington.

Limited information about the production of construction sand and gravel in foreign countries may be found in the USGS Minerals Yearbook, Volume III, Area Reports: International. For nonreporting countries, estimates of sand and gravel and crushed stone outputs can be based on indirect indicators, such as the level of asphalt and cement consumption.

After receiving approval votes from most of their member companies, effective September 30, 2000, the National Aggregates Association and the National Stone Association merged to form the National Stone, Sand, and Gravel Association. The new association will be the sole organization representing the crushed stone and sand and gravel producing companies at the national level.

During the past 4 years (1997-2000), more than 150 acquisitions have been announced, at a rate of almost one per week. The industry consolidation is expected to continue at a very rapid pace (Aggregates Manager, 2000d).

In an industry with thousands of operating companies, there are many operating status and ownership changes. Although reviewing them all is not possible, a few noteworthy events follow.

On January 1, Aggregates Industries, Inc., announced that all its divisions would now do business under the name Aggregates Industries, dropping the individual names the divisions had been using, such as CAMAS Minnesota or Bardon Trimount (Aggregates Manager, 2000b). In 2000, Aggregates Industries was the third largest producer of sand and gravel in the United States, after ending 1999 as the fourth largest producer.

CRH plc purchased The Shelley Co. in February. The purchase included 10 sand and gravel pits and 64 fixed or portable asphalt plants (Aggregates Manager, 2000a).

Martin Marietta Materials Inc. purchased B&B Gravel Co. and three other companies in February. The purchase added 3.3 Mt/yr of capacity including sand and gravel and crushed stone (Aggregates Manager, 2000a).

In May, Florida Rock Industries, Inc., bought 12 ready-mix plants, 2 concrete block plants, and 2 sand mines from Southern Concrete Construction Co., Albany, GA. The two sand mines are located in Albany, GA, and Bainbridge, GA (Rock Products, 2000b).

Hanson plc became the largest producer of sand and gravel in the United States in 2000 with the purchase of Pioneer Concrete of America, Inc., in May, 2000. Hanson was the second largest producer in 1999 and switched positions with Vulcan Materials Co., which was the largest producer in 1999 (Rock Products, 2000a).

In March, Anglo American plc announced the purchase of Tarmac plc. In October, Anglo American sold Tarmac America, Inc., to Titan Cement Co. S.A. Titan then agreed to sell the non-Florida construction aggregate parts of Tarmac America to Vulcan Materials. This included crushed stone quarries in South Carolina and Pennsylvania and a distribution operation in Baltimore, MD. Also included were crushed stone quarries, sand and gravel operations, and marine operations in Virginia. Vulcan finalized the purchases of these operations in October and November. The remaining Tarmac America operations owned by Titan Cement will continue to do business under the name of Tarmac America (Pit and Quarry, 2000e).

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In June, CSR America, Inc., agreed to purchase the aggregates and cement company FCH Holdings, Inc., and its subsidiary, Florida Crushed Stone Co. (Pit and Quarry, 2000d).

Texas Industries, Inc. (TXI), purchased Central Sand and Gravel Co. Inc. of Jena, LA, in July. Central Sand and Gravel is a primary supplier of asphalt and concrete fine and coarse aggregates in Louisiana (Pit and Quarry, 2000b). Also in July, TXI acquired Collier Sand and Gravel Co., Marble Falls, TX (Rock Products, 2000c). With these acquisitions, TXI became the 15th largest producer of sand and gravel in the United States after finishing as the 24th largest in 1999.

In September, Martin Marietta announced the purchase of the last part of Meridian Aggregates Co. that it did not own (Pit and Quarry, 2000c).

CEMEX S.A. de C.V. completed the purchase of Southdown, Inc., in November. Southdown was the seventh largest producer of sand and gravel in the United States in 1999. In 2000, CEMEX was the sixth largest producer (Pit and Quarry, 2000a).

Consumption

Construction sand and gravel reported by producers to the USGS was actually material that was "sold or used" by the companies and was defined as such. Stockpiled production is not reported until it is sold or consumed by the producer. Because no consumption surveys are conducted by the USGS for sand and gravel, the "sold or used" tonnage is assumed to represent the amount produced for domestic consumption and export. Because some of the construction sand and gravel producers did not report a breakdown by end use, their total production was reported under "Unspecified uses, reported." The estimated production of nonrespondents was reported under "Unspecified uses, estimated."

Of the 1.12 Gt of construction sand and gravel produced in 2000, 514 Mt, or 45.9% of the total, was for unspecified uses (table 6). Of the remaining 606 Mt, 43.7% was used as concrete aggregates; 22.7%, for road base and coverings and road stabilization; 13.1%, for asphaltic concrete aggregates and other bituminous mixtures; 13.3%, for construction fill; 1.7%, for plaster and gunite sands; 1.6%, for concrete products, such as blocks, bricks, pipes, etc.; and the remainder, for filtration, railroad ballast, roofing granules, snow and ice control, and other miscellaneous uses.

To provide a more accurate estimation of the consumption patterns for construction sand and gravel, the "Unspecified uses" are not included in the above percentages. In any marketing or use pattern analysis, the quantities included in "Unspecified uses" should be distributed among the reported uses by applying the above percentages.

Compared with 1999, nearly 2% more of the sand and gravel produced was reported for specific uses and this must be taken into account when analyzing changes in market consumption. Consumption increased for the following markets: filtration (about 49%), roofing granules (about 18%), concrete aggregates and miscellaneous uses (each about 11%), and fill (about 5%). Consumption decreased by about 42% for road stabilization (lime), by 12.3% for road stabilization (cement), by 4.8% for concrete products, by 2.7% for snow and ice control, and by less than 2% for plaster and gunite sands. Sand and gravel consumption for road base and coverings and railroad ballast remained at 1999 levels.

Additional information regarding production and/or consumption of construction sand and gravel by major uses in each State and the State districts may be found in the USGS Minerals Yearbook, volume II, Area Reports: Domestic.

Recycling

The aggregates industry has been involved with recycling for several decades. Recently, recycling has become more important to aggregate producers, and the number of aggregate companies that are recycling has been increasing. Recycling in this industry generally refers to the crushing, screening, and reuse of cement and asphalt concretes. Aggregate and related asphalt and ready-mix companies are often involved in construction projects where they collect and reuse the materials at the site. Some construction companies haul their materials to the recycling location where the asphalt or concrete is processed for reuse. The annual survey of construction sand and gravel producers collects information on recycling of cement and asphalt concrete performed only by sand and gravel producing companies. No information on recycling of these materials by construction or demolition companies is collected by the USGS.

Asphalt Concrete.—A total of 4.74 Mt of asphalt concrete valued at $21.6 million was recycled by 198 sand and gravel companies in 39 States; this volume represented a 26% decrease compared with that of 1999 (tables 14, 15). Leading States, in descending order of tonnage recycled, were California, Minnesota, and Wisconsin. Leading companies, in order of volume produced, were Granite Construction Co.; Red Flint Group, LLC; Provident Engineering and Development Co.; Memphis Stone and Gravel Co.; and Central Specialties, Inc.

Cement Concrete.—A total of 7.21 Mt of cement concrete valued at $32.6 million was recycled by 182 companies in 35 States; this volume represented a 7.9% increase compared with that of 1999 (tables 14, 16). Leading States, in descending order of tonnage recycled, were California, Minnesota, Michigan, and Wisconsin. Leading companies, in order of volume produced, were Premier Aggregates, Inc.; Vulcan Materials; Custom Crushing and Recycling, Inc.; Red Flint Group; and Provident Engineering and Development.

Transportation

Information regarding the method of transportation of construction sand and gravel from the pit or processing plant to the first point of sale or use is available for each geographic region, as well as for the total United States, and is listed in table 11. Reports regarding the method of transportation were provided by the producers for 547 Mt, or 49% of the total U.S. production, of construction sand and gravel. Of this total, 78.8% was transported by truck; 3.1%, by waterway; and 1.6%, by rail. A significant amount of construction sand and gravel produced (about 15%) was not transported but was used at the production site. Because most producers either did not keep records or did not report shipping distances or cost per metric ton per mile, no transportation cost data were available.

Prices

Prices in this chapter are "free on board" (f.o.b.) plant, usually at the first point of sale or captive use. This value does not include transportation from the plant or yard to the

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consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs, and profit.

The 2000 average unit price increased by about 1.7% to $4.81 per metric ton, compared with that of 1999 (table 6). By use, the unit prices varied from a high of $12.35 per ton for roofing granules to a low of $3.09 per ton for fill. The largest increases were recorded for roofing granules (80.6%), railroad ballast (18.7%), and road stabilization (cement) (16.2%). Only two markets recorded declines: concrete products (4.2%) and other uses (1.8%).

Foreign Trade

The widespread distribution of domestic sand and gravel deposits and the high cost of transportation limits foreign trade to mostly local transactions across international boundaries. U.S. imports and exports were small, representing less than 1% of the domestic consumption.

Exports of construction sand increased by about 69% to 2.14 Mt compared with that of 1999 and the value increased by nearly 2% to $21.2 million (table 12). Mexico was the major destination, receiving about 75% of the total, followed by Canada with nearly 16%. Exports of construction gravel decreased by almost 29% to 270,000 metric tons, and the value decreased by about 57% to $3.03 million. Canada was the major destination, receiving about 84% of the total.

Imports increased by about 49% to 2.87 Mt, and the value increased by about 36% to $33.3 million (table 13). Canada was the major source of imported construction sand and gravel with 56% of the total, followed by Mexico with about 25%.

Outlook

The demand for construction sand and gravel in 2001 is expected to be about equal to that of 2000 in response to a slowing national economy. There are some indications from the quarterly survey that a slowing economy has stalled growth in aggregate demand through the first half of 2001 but some regions of the United States should see increased sales so that overall demand will likely remain close to 2000 levels.

Construction sand and gravel f.o.b. prices are expected to increase only marginally. The delivered prices of construction sand and gravel, however, are expected to increase especially in and near metropolitan areas mainly because more aggregates are transported from distant sources.

For 2001, the industry is expected to continue to consolidate. Resistance to mining, especially at the local level, will push production to more rural areas and increase transportation cost. The cost to acquire existing companies will escalate because of the difficulty of starting greenfield operations. It is estimated that it now takes from 5 to 8 years to put a new resource (greenfield) into production. This includes the time it takes to prove the reserve base, receive zoning and permit approvals, and to deliver and install the necessary equipment. Also, throughout the process, the possibility exists that the project may have to be abandoned because of local opposition and permit or zoning denial; therefore, many companies prefer to buy already permitted active operations rather than face the cost and uncertainties involved with a greenfield operation.

References Cited

Aggregates Manager, 2000a, Acquisitions and mergers: Aggregates Manager, v. 4, no. 12, March, p. 11.

———2000b, Aggregate Industries unifies division names: Aggregates Manager, v. 4, no. 11, February, p. 7.

———2000c, Corp's new nationwide permit restrictions leave producers very little room to maneuver: Aggregates Manager, v. 5, no. 3, June, p. 37.

———2000d, Rapid industry consolidation expected to continue: Aggregates Manager, v. 4, no. 12, March, p. 31-34.

Mine Safety and Health Administration, 1999, New standards add protections for miners exposed to noise: Washington, DC, Mine Safety and Health Administration news release no. 99-0909, September 9, 1 p.

Pit and Quarry, 2000a, Cemex to acquire Southdown in $2.8 billion transaction: Pit and Quarry, v. 93, no. 5, November, p. 10.

———2000b, Industry sees further consolidation: Pit and Quarry, v. 93, no. 2, August, p. 12.

———2000c, Martin Marietta buys rest of Meridian Aggregates: Pit and Quarry, v. 93, no. 4, October, p. 17.

———2000d, Out in front: Pit and Quarry, v. 93, no. 1, July, p. 2

———2000e, Titan Cement to acquire Tarmac America, sell portion to Vulcan: Pit and Quarry, v. 93, no. 4, October, p. 14-15.

Rock Products, 2000a, Industry news: Rock Products, v. 103, no. 6, June, p. 14.

———2000b, News scope: Rock Products, v. 103, no. 6, June, p. 7.

———2000c, TXI on the move in Texas and Louisiana: Rock Products, v. 103, no. 8, August, p. 7.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Crushed Stone and Sand and Gravel. Mineral Industry Surveys, quarterly.
Directory of Principal Crushed Stone Producers. Mineral Industry Surveys, annual.
Directory of Principal Sand and Gravel Producers. Mineral Industry Surveys, annual.
Directory of State Publications Listing Crushed Stone and Sand and Gravel Producers, biennial.
Sand and Gravel. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Sand and Gravel, Construction. Ch. in Mineral Commodity Summaries, annual.
Stone, Crushed. Ch. in Mineral Commodity Summaries, annual.
Stone, Crushed. Ch. in Minerals Yearbook, annual.

Other

Aggregates for Construction Purposes. The Geological Society, United Kingdom, 1985.
Aggregates Handbook. National Stone Association, 1991.
Aggregates Manager.
Canadian Aggregates.
Concrete Manual. A Water Resources Publication, U.S. Department of the Interior, Bureau of Reclamation, 1975.
Earth Manual. A Water Resources Publication, U.S. Department of the Interior, Bureau of Reclamation, 1974.
Geology of Nonmetallics. Bates, R.L., and Harben, P.W., Metal Bulletin Inc., 1984.
Handbook of Concrete Aggregates—A Petrographic and Technological Evaluation. Dolar-Mantuani, Ludmila, Noyes Publications, 1983.
Industrial Minerals Magazine.
Pit & Quarry.
Quarry Management.
Rock Products.
Sand and Gravel.

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TABLE 1
SALIENT U.S. CONSTRUCTION SAND AND GRAVEL STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
Sold or used by producers:					
Quantity 2/	914,000 3/	952,000	1,070,000	1,110,000	1,120,000
Value 2/	4,000,000 3/	4,260,000	4,910,000	5,250,000	5,390,000
Exports, value	23,300	22,300	37,800	27,900	24,200
Imports, value	15,800	18,100	15,000	24,400	33,300

1/ Data are rounded to no more than three significant digits.
2/ Puerto Rico excluded from all sand and gravel statistics.
3/ Excludes Hawaii.

TABLE 2
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION 1/

	1999				2000			
Region/division	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	41,500	3.7	$213,000	4.1	44,900	4.0	$235,000	4.3
Middle Atlantic	64,900	5.9	359,000	6.8	63,900	5.7	349,000	6.5
Midwest:								
East North Central	221,000	20.0	903,000	17.2	225,000	20.0	927,000	17.2
West North Central	110,000	9.9	403,000	7.7	108,000	9.6	396,000	7.3
South:								
South Atlantic	79,900	7.2	375,000	7.2	83,300	7.4	406,000	7.5
East South Central	46,800	4.2	213,000	4.1	45,900	4.1	208,000	3.8
West South Central	115,000	10.4	549,000	10.5	115,000	10.2	569,000	10.5
West:								
Mountain	213,000	19.2	949,000	18.1	218,000	19.5	988,000	18.3
Pacific	215,000	19.4	1,280,000	24.5	218,000	19.4	1,320,000	24.4
Total	1,110,000	100	5,250,000	100	1,120,000	100	5,390,000	100

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3
SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY QUARTER AND DIVISION 1/

	Quantity 1st quarter		Quantity 2d quarter		Quantity 3d quarter		Quantity 4th quarter		Total 2/	
Region/division	(thousand metric tons)	Percentage change 3/	(thousand metric tons)	Percentage change 3/	(thousand metric tons)	Percentage change 3/	(thousand metric tons)	Percentage change 3/	Quantity (thousand metric tons)	Value (thousands)
Northeast:										
New England	5,400	4.5	12,000	1.3	15,200	9.4	10,300	(1.8)	43,000	$228,000
Middle Atlantic	8,800	6.8	19,600	3.0	22,900	0.4	14,800	(1.1)	66,000	375,000
Midwest:										
East North Central	28,800	7.1	63,600	(0.1)	70,300	(4.2)	53,600	(6.9)	216,000	907,000
West North Central	11,900	16.9	36,700	13.7	40,600	(0.6)	21,700	(19.3)	111,000	427,000
South:										
South Atlantic	19,300	3.3	22,400	1.5	21,800	5.3	20,100	9.1	83,600	412,000
East South Central	9,200	3.8	13,400	2.5	12,500	(16.5)	9,700	(2.2)	44,800	209,000
West South Central	31,400	15.0	32,900	12.1	37,600	24.7	28,900	2.2	131,000	659,000
West:										
Mountain	43,900	(9.8)	63,400	15.3	64,300	8.8	57,700	14.1	229,000	1,040,000
Pacific 4/	40,200	6.2	59,000	13.7	65,800	9.4	57,100	2.4	222,000	1,350,000
Total 2/	199,000	3.7	323,000	8.3	351,000	4.5	274,000	0.4	1,160,000 5/	5,610,000 5/

1/ As published in the Crushed Stone and Sand and Gravel in the Fourth Quarter of 2000 Mineral Industry Surveys.
2/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.
3/ All percentage changes are calculated by using unrounded totals; percentage changes are based on the previous year's corresponding quarter.
4/ Does not include Alaska and Hawaii.
5/ Includes Alaska and Hawaii.

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TABLE 4
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	15,500	$68,900	$4.45	14,500	$63,700	$4.41
Alaska 2/	9,620	48,500	5.04	10,600	53,500	5.06
Arizona	54,500	296,000	5.42	59,400	304,000	5.12
Arkansas	11,300	53,200	4.72	9,820	48,600	4.95
California	145,000	897,000	6.20	148,000	940,000	6.34
Colorado	45,200	217,000	4.80	43,900	216,000	4.92
Connecticut	6,510	32,400	4.98	8,010	46,900	5.85
Delaware	2,100	10,800	5.14	2,330	12,400	5.34
Florida	27,200	114,000	4.19	24,500	107,000	4.39
Georgia	7,200	30,100	4.18	6,940	28,700	4.13
Hawaii	508	5,840	11.50	607	6,420	10.57
Idaho	15,500	48,200	3.12	17,500	55,700	3.18
Illinois	34,100	147,000	4.32	30,300	132,000	4.35
Indiana	29,500	126,000	4.26	27,900	121,000	4.33
Iowa	13,500	60,600	4.49	12,300	54,100	4.40
Kansas	10,800	31,300	2.91	10,000	28,200	2.81
Kentucky	9,620	32,400	3.37	11,000	36,000	3.28
Louisiana	16,500	81,700	4.96	14,900	76,900	5.17
Maine	8,570	40,300	4.70	9,670	37,600	3.89
Maryland	8,970	56,500	6.29	13,100	84,700	6.48
Massachusetts	12,700	75,200	5.90	13,200	80,100	6.07
Michigan	70,200	245,000	3.48	75,600	269,000	3.55
Minnesota	37,300	142,000	3.80	39,500	158,000	4.00
Mississippi	12,100	58,900	4.88	11,700	60,900	5.21
Missouri	12,400	50,300	4.05	10,700	41,700	3.89
Montana	12,000	50,700	4.22	9,950	40,600	4.08
Nebraska	12,000	40,800	3.40	11,700	39,200	3.34
Nevada	31,700	142,000	4.48	36,800	172,000	4.67
New Hampshire	7,950	36,700	4.62	8,660	41,400	4.78
New Jersey	16,500	91,500	5.55	16,300	85,000	5.22
New Mexico	10,600	53,000	4.99	13,400	66,800	4.97
New York	29,900	152,000	5.10	29,700	154,000	5.18
North Carolina	11,600	62,900	5.43	12,000	59,100	4.93
North Dakota	11,700	33,000	2.83	10,600	27,800	2.62
Ohio	52,000	257,000	4.95	51,200	256,000	5.01
Oklahoma	10,200	41,200	4.04	9,210	35,500	3.85
Oregon	16,900	105,000	6.20	16,500	97,000	5.89
Pennsylvania	18,600	115,000	6.20	17,900	110,000	6.13
Rhode Island	1,310	9,900	7.56	1,240	9,780	7.92
South Carolina	9,660	38,200	3.96	10,300	40,800	3.95
South Dakota	12,400	45,600	3.67	12,800	46,500	3.64
Tennessee	9,640	53,100	5.50	8,760	47,000	5.37
Texas	77,100	373,000	4.83	80,800	408,000	5.04
Utah	39,500	125,000	3.17	30,900	109,000	3.52
Vermont	4,430	18,800	4.24	4,140	18,800	4.55
Virginia	11,300	53,800	4.75	12,100	63,200	5.20
Washington	43,800	227,000	5.18	41,800	221,000	5.29
West Virginia	1,850	9,030	4.88	1,980	9,800	4.94
Wisconsin	35,700	128,000	3.59	39,600	150,000	3.78
Wyoming	4,410	17,200	3.91	6,340	23,800	3.75
Total	1,110,000	5,250,000	4.73	1,120,000	5,390,000	4.81

1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Data derived in part from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 5
SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY QUARTER AND STATE 1/

State	Quantity 1st quarter (thousand metric tons)	Percent-age change 3/	Quantity 2d quarter (thousand metric tons)	Percent-age change 3/	Quantity 3d quarter (thousand metric tons)	Percent-age change 3/	Quantity 4th quarter (thousand metric tons)	Percent-age change 3/	Total 2/ (thousand metric tons)	Value total 2/ (thousands)
Alabama	3,600	4.1	4,400	8.3	4,000	(5.0)	3,300	(9.4)	15,400	$69,900
Alaska 4/	--	--	--	--	--	--	--	--	10,000	52,000
Arizona	13,000	(5.8)	16,500	16.2	15,800	16.1	15,100	17.0	60,400	339,000
Arkansas	2,700	11.1	2,700	(6.1)	3,100	(4.7)	2,300	(16.5)	10,800	52,500
California	28,700	7.1	40,500	12.7	47,600	13.9	41,900	3.6	159,000	1,010,000
Colorado	8,100	(9.1)	13,300	15.3	14,200	2.6	11,400	4.9	47,000	231,000
Connecticut	1,200	40.5	2,500	28.0	2,300	13.2	1,500	(12.5)	7,450	37,800
Delaware 5/	--	--	--	--	--	--	--	--	2,080	11,200
Florida	6,600	0.7	7,100	1.0	6,800	(1.2)	6,600	(2.8)	27,100	119,000
Georgia	1,800	4.7	1,900	(6.2)	2,000	5.6	1,900	15.7	7,510	31,900
Hawaii 4/	--	--	--	--	--	--	--	--	500	5,900
Idaho	1,900	(2.2)	4,700	10.1	6,100	6.2	4,200	17.2	16,800	54,100
Illinois	3,900	(1.1)	8,500	(17.8)	9,700	(5.3)	7,600	(19.7)	29,800	132,000
Indiana	6,000	4.8	8,300	(5.7)	8,100	(5.3)	6,300	(1.2)	28,700	125,000
Iowa	1,200	10.8	4,000	0.9	3,800	(23.5)	3,300	(9.3)	12,200	56,300
Kansas	2,000	15.9	3,100	16.7	2,700	(25.6)	2,200	(23.6)	9,920	29,300
Kentucky	1,600	(1.9)	2,700	(4.3)	2,900	6.2	2,400	(5.5)	9,500	32,500
Louisiana	3,700	(5.8)	4,100	(10.7)	5,300	30.6	3,800	(3.9)	16,900	85,400
Maine	500	(13.0)	2,500	5.7	3,700	11.2	2,400	3.9	9,100	43,700
Maryland	2,500	29.3	3,200	34.9	3,100	30.9	2,800	19.5	11,500	74,300
Massachusetts	2,100	3.1	3,500	(7.3)	4,100	18.6	3,600	7.8	13,400	80,600
Michigan	7,000	5.9	22,700	16.4	25,300	0.8	19,000	0.3	74,000	265,000
Minnesota	1,500	(3.0)	13,000	11.3	16,800	9.0	7,100	(19.0)	38,300	150,000
Mississippi	2,100	0.3	3,300	0.0	3,100	(27.5)	2,200	(4.5)	10,800	54,000
Missouri	2,300	22.0	3,600	14.3	3,500	(12.0)	2,400	(27.0)	11,900	49,400
Montana 5/	--	--	--	--	--	--	--	--	12,800	55,700
Nebraska	1,700	23.1	4,500	11.4	4,800	12.5	1,800	(21.6)	12,800	46,100
Nevada	8,300	10.9	9,500	22.2	9,600	21.9	8,600	0.6	36,000	166,000
New Hampshire	1,100	(3.6)	2,000	0.2	3,100	1.7	1,700	(6.7)	7,840	37,400
New Jersey	3,100	1.3	3,500	(19.1)	4,400	(5.1)	3,900	(12.1)	14,900	85,000
New Mexico	2,300	7.2	2,800	8.7	3,200	26.9	2,400	(26.8)	10,800	55,200
New York	3,500	3.0	10,200	17.0	12,400	4.9	7,200	20.4	33,300	174,000
North Carolina	3,400	42.7	2,900	(12.9)	3,000	(2.0)	2,900	3.6	12,200	68,600
North Dakota 4/	--	--	--	--	--	--	--	--	11,700	34,000
Ohio	7,000	11.8	13,400	(5.6)	16,000	(10.2)	12,200	(10.9)	48,600	246,000
Oklahoma	2,500	7.3	2,700	15.4	3,000	0.7	2,000	(22.2)	10,200	41,800
Oregon	2,600	(13.0)	5,100	5.3	5,100	(6.0)	3,900	4.2	16,600	106,000
Pennsylvania	2,100	19.5	6,100	4.1	6,500	(1.3)	3,900	(10.1)	18,700	116,000
Rhode Island 5/	--	--	--	--	--	--	--	--	1,400	11,200
South Carolina	2,400	(11.8)	2,800	(0.4)	2,800	5.9	2,400	53.2	10,300	41,500
South Dakota	1,700	42.7	5,800	60.0	6,000	29.1	2,700	(5.8)	16,300	61,700
Tennessee	1,800	12.8	3,000	0.2	2,700	(23.9)	2,000	25.8	9,420	53,000
Texas	23,500	24.8	24,600	25.3	27,200	38.6	22,000	15.4	97,300	479,000
Utah	4,700	(46.6)	11,800	12.7	11,500	(10.5)	11,600	59.3	39,700	126,000
Vermont	300	(23.9)	1,100	(27.2)	1,400	4.5	1,100	(9.6)	3,880	17,200
Virginia	2,500	(11.8)	3,400	2.2	3,100	19.1	2,900	15.8	11,900	57,600
Washington	8,500	6.7	14,200	21.3	12,300	(8.9)	10,000	(6.0)	45,000	235,000
West Virginia	200	(4.9)	500	(20.0)	500	(23.9)	300	(8.8)	1,530	7,590
Wisconsin	3,900	19.4	11,800	10.1	12,400	(0.9)	9,200	(1.0)	37,200	139,000
Wyoming	1,200	2.5	900	7.5	800	(11.3)	1,200	(21.6)	4,080	16,700
Total	XX	XX	XX	XX	XX	XX	XX	XX	1,160,000	5,610,000

XX Not applicable. -- Zero.

1/ As published in the Crushed Stone and Sand and Gravel in the Fourth Quarter of 2000 Mineral Industry Surveys.

2/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.

3/ All percentage changes are calculated by using unrounded totals; percentage changes are based on the previous year's corresponding quarter.

4/ State not included in quarterly survey.

5/ Owing to a low number of reporting companies, no production estimates by quarters were generated.

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TABLE 6
CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES IN 2000, BY MAJOR USE 1/

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Concrete aggregates (including concrete sand)	265,000	$1,450,000	$5.48
Plaster and gunite sands	10,200	62,800	6.15
Concrete products (blocks, bricks, pipe, decorative, etc.)	9,810	62,000	6.32
Asphaltic concrete aggregates and other bituminous mixtures	79,500	452,000	5.69
Road base and coverings	132,000	568,000	4.31
Road stabilization (cement)	3,340	17,000	5.10
Road stabilization (lime)	2,520	9,880	3.93
Fill	80,800	250,000	3.09
Snow and ice control	5,360	22,000	4.11
Railroad ballast	1,070	7,160	6.67
Roofing granules	471	5,820	12.35
Filtration	1,720	10,500	6.10
Other miscellaneous uses	15,300	85,700	5.59
Unspecified: 2/			
Actual	269,000	1,290,000	4.79
Estimated	245,000	1,100,000	4.50
Total	1,120,000	5,390,000	4.81

1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Reported and estimated production without a breakdown by end use.

TABLE 7
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION AND MAJOR USE 1/

(Thousand metric tons and thousand dollars)

Region/division	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures		Road base and coverings 2/	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	7,330	48,900	87	1,020	353	2,050	2,780	17,000	5,720	27,500
Middle Atlantic	13,500	78,300	441	2,660	1,070	7,370	5,130	29,600	6,440	28,800
Midwest:										
East North Central	36,300	156,000	640	3,340	1,980	10,900	14,600	64,400	28,000	106,000
West North Central	24,100	111,000	640	3,150	1,070	5,960	8,850	35,400	23,600	69,900
South:										
South Atlantic	28,300	141,000	1,420	6,580	2,010	9,550	1,980	8,590	4,060	16,400
East South Central	13,300	64,500	340	2,540	583	3,460	4,190	23,400	3,100	13,600
West South Central	41,800	228,000	1,470	8,500	473	2,430	2,380	16,600	4,550	22,300
West:										
Mountain	41,800	229,000	945	8,990	1,100	10,400	13,300	73,300	32,700	136,000
Pacific	58,400	394,000	4,240	26,000	1,170	9,910	26,300	184,000	29,700	174,000
Total	265,000	1,450,000	10,200	62,800	9,810	62,000	79,500	452,000	138,000	595,000

Region/division	Fill		Snow and ice control		Railroad ballast		Other uses		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	3,520	11,700	1,320	6,050	176	1,150	23,600	119,000	44,900	235,000
Middle Atlantic	5,820	23,300	1,160	4,610	86	623	30,300	173,000	63,900	349,000
Midwest:										
East North Central	17,300	51,100	1,190	3,800	37	357	124,000	531,000	225,000	927,000
West North Central	6,380	13,600	822	2,910	6	46	42,200	154,000	108,000	396,000
South:										
South Atlantic	7,540	21,900	W	W	W	W	37,800	201,000	83,300	406,000
East South Central	1,150	3,920	4	14	--	--	23,200	96,300	45,900	208,000
West South Central	10,000	22,500	W	W	W	W	54,000	267,000	115,000	569,000
West:										
Mountain	14,600	37,600	524	2,770	232	1,030	113,000	488,000	218,000	988,000
Pacific	14,500	63,900	201	1,180	455	3,210	82,800	462,000	218,000	1,320,000
Total	80,800	250,000	5,370	22,000	1,070	7,160	531,000	2,490,000	1,120,000	5,390,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes road and other stabilization (cement and lime).

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TABLE 8
CONSTRUCTION SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2000, BY REGION AND SIZE OF OPERATION 1/

Size range (metric tons)	Northeast				Midwest				South			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	376	35.6	3,370	3.1	541	24.6	5,350	1.6	237	21.2	2,210	0.9
25,000 to 49,999	163	15.4	5,410	5.0	337	15.3	11,200	3.4	111	9.9	3,750	1.5
50,000 to 99,999	171	16.2	11,100	10.2	437	19.9	28,500	8.6	200	17.9	12,900	5.3
100,000 to 199,999	175	16.6	22,200	20.4	357	16.3	45,700	13.8	192	17.2	25,000	10.2
200,000 to 299,999	78	7.4	16,900	15.6	176	8.0	39,200	11.8	105	9.4	22,900	9.4
300,000 to 399,999	27	2.6	8,370	7.7	88	4.0	27,200	8.2	64	5.7	20,400	8.4
400,000 to 499,999	22	2.1	8,890	8.2	77	3.5	31,100	9.4	45	4.0	18,100	7.4
500,000 to 599,999	17	1.6	8,500	7.8	41	1.9	20,200	6.1	34	3.0	16,900	6.9
600,000 to 699,999	8	0.8	4,650	4.3	44	2.0	26,300	7.9	24	2.2	14,400	5.9
700,000 to 799,999	5	0.5	3,380	3.1	32	1.5	21,400	6.5	23	2.1	15,800	6.5
800,000 to 899,999	6	0.6	4,460	4.1	17	0.8	13,000	3.9	14	1.3	10,700	4.4
900,000 to 999,999	1	0.1	894	0.8	13	0.6	11,200	3.4	12	1.1	10,300	4.2
1,000,000 to 1,499,999	5	0.5	5,770	5.3	19	0.9	20,400	6.1	39	3.5	43,000	17.6
1,500,000 to 1,999,999	2	0.2	W	W	10	0.5	W	W	11	1.0	17,300	7.1
2,000,000 to 2,499,999	1	0.1	W	W	5	0.2	10,300	3.1	4	0.4	W	W
2,500,000 to 4,999,999	--	--	--	--	2	0.1	W	W	1	0.1	W	W
5,000,000 and over	--	--	--	--	--	--	--	--	--	--	--	--
Total	1,057	100	109,000	100	2,196	100	332,000	100	1,116	100	244,000	100

Size range (metric tons)	West				U.S. total			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	512	27.9	4,230	1.0	1,666	26.9	15,200	1.4
25,000 to 49,999	229	12.5	7,440	1.7	840	13.5	27,800	2.5
50,000 to 99,999	293	16.0	19,200	4.4	1,101	17.7	71,800	6.4
100,000 to 199,999	232	12.6	29,800	6.8	956	15.4	123,000	11.0
200,000 to 299,999	155	8.4	34,600	7.9	514	8.3	114,000	10.1
300,000 to 399,999	87	4.7	27,000	6.2	266	4.3	82,900	7.4
400,000 to 499,999	59	3.2	23,900	5.5	203	3.3	82,000	7.3
500,000 to 599,999	52	2.8	25,700	5.9	144	2.3	71,300	6.4
600,000 to 699,999	34	1.9	20,000	4.6	110	1.8	65,300	5.8
700,000 to 799,999	35	1.9	23,800	5.5	95	1.5	64,500	5.8
800,000 to 899,999	22	1.2	16,900	3.9	59	1.0	45,100	4.0
900,000 to 999,999	16	0.9	13,800	3.2	42	0.7	36,200	3.2
1,000,000 to 1,499,999	53	2.9	57,900	13.3	116	1.9	127,000	11.3
1,500,000 to 1,999,999	19	1.0	30,300	7.0	42	0.7	66,300	5.9
2,000,000 to 2,499,999	17	0.9	33,100	7.6	27	0.4	53,200	4.7
2,500,000 to 4,999,999	17	0.9	52,200	12.0	20	0.3	60,100	5.4
5,000,000 and over	3	0.2	16,000	3.7	3	0.0	16,000	1.4
Total	1,835	100	436,000	100	6,204	100	1,120,000	100

W Withheld to avoid disclosing company proprietary data; included in "total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 9
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION

Region/division	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	179	195	41	29	1	445
Middle Atlantic	201	266	52	61	32	612
Midwest:						
East North Central	436	466	107	112	108	1,229
West North Central	209	413	39	69	237	967
South:						
South Atlantic	130	46	14	65	141	396
East South Central	115	26	10	19	60	230
West South Central	205	74	16	74	121	490
West:						
Mountain	352	527	92	137	19	1,127
Pacific 1/	318	209	71	74	36	708
Total	2,145	2,222	442	640	755	6,204

1/ An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

TABLE 10
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2000, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plant or unspecified		
Alabama	44	11	--	8	18	81
Alaska	11	8	2	6	4	31
Arizona	70	75	21	9	2	177
Arkansas	40	10	2	3	6	61
California	191	80	34	27	14	346
Colorado	75	128	17	23	8	251
Connecticut	28	22	7	2	--	59
Delaware	1	2	--	2	4	9
Florida	18	3	1	5	38	65
Georgia	16	1	--	3	28	48
Hawaii	1	3	--	2	--	6
Idaho	33	72	3	26	3	137
Illinois	52	35	19	12	40	158
Indiana	71	25	18	5	29	148
Iowa	40	60	6	8	35	149
Kansas	12	30	3	14	51	110
Kentucky	9	3	3	1	14	30
Louisiana	16	8	--	9	66	99
Maine	39	77	5	12	--	133
Maryland	18	7	4	10	2	41
Massachusetts	64	15	10	3	1	93
Michigan	134	186	31	37	7	395
Minnesota	56	148	19	22	5	250
Mississippi	35	4	5	7	18	69
Missouri	38	11	--	1	30	80
Montana	44	67	10	11	1	133
Nebraska	9	14	1	4	116	144
Nevada	28	37	15	10	--	90
New Hampshire	23	36	8	2	--	69
New Jersey	29	6	5	3	13	56
New Mexico	36	43	9	19	--	107
New York	108	229	35	48	11	431
North Carolina	24	20	3	21	30	98
North Dakota	26	64	4	1	--	95
Ohio	110	33	18	30	28	219
Oklahoma	16	9	2	13	31	71
Oregon	39	32	12	17	4	104
Pennsylvania	64	31	12	10	8	125
Rhode Island	8	1	3	--	--	12

See footnote at end of table.

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TABLE 10--Continued
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2000, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plant or unspecified		
South Carolina	17	4	1	9	21	52
South Dakota	28	86	6	19	--	139
Tennessee	27	8	2	3	10	50
Texas	133	47	12	49	18	259
Utah	53	67	14	18	2	154
Vermont	17	44	8	10	--	79
Virginia	25	5	5	13	14	62
Washington	76	86	23	22	14	221
West Virginia	11	4	--	2	4	21
Wisconsin	69	187	21	28	4	309
Wyoming	13	38	3	21	3	78
Total	2,145	2,222	442	640	755	6,204

-- Zero.

TABLE 11
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY REGION AND METHOD OF TRANSPORTATION 1/

(Thousand metric tons)

Region/division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	15,500	1,090	--	123	3,220	25,000	44,900
Middle Atlantic	27,900	18	876	343	3,290	31,500	63,900
Midwest:							
East North Central	73,700	299	3,990	1,190	14,600	131,000	225,000
West North Central	42,800	540	4,030	25	13,700	46,600	108,000
South:							
South Atlantic	43,000	1,870	467	101	2,270	35,600	83,300
East South Central	19,500	121	1,280	42	1,610	23,400	45,900
West South Central	43,500	2,900	2,510	525	7,390	57,900	115,000
West:							
Mountain	71,600	440	--	373	13,900	132,000	218,000
Pacific	93,900	1,220	3,580	5,990	22,800	90,200	218,000
Total	431,000	8,490	16,700	8,710	82,700	573,000	1,120,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 12
U.S. EXPORTS OF CONSTRUCTION SAND AND GRAVEL IN 2000, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country or territory	Sand		Gravel	
	Quantity	F.a.s. value 2/	Quantity	F.a.s. value 2/
North America:				
Bahamas, The	17	653	1	23
Canada	335	6,180	228	1,410
Mexico	1,610	3,760	1	124
Netherlands Antilles	3	34	2	19
Trinidad and Tobago	(3/)	3	--	--
Other 4/	3	391	(3/)	32
Total	1,970	11,000	232	1,610
South America:				
Argentina	(3/)	117	1	84
Ecuador	(3/)	332	--	--
Peru	(3/)	38	--	--
Venezuela	5	285	(3/)	66
Other 5/	4	199	(3/)	1
Total	9	971	1	151
Europe:				
Belgium	2	108	(3/)	46

See footnotes at end of table.

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TABLE 12--Continued
U.S. EXPORTS OF CONSTRUCTION SAND AND GRAVEL IN 2000, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country or territory	Sand		Gravel	
	Quantity	F.a.s. value 2/	Quantity	F.a.s. value 2/
Europe--Continued:				
Germany	42	917	(3/)	23
Spain	--	--	2	70
Sweden	(3/)	91	--	--
United Kingdom	25	1,270	1	78
Other 6/	41	725	6	242
Total	110	3,110	9	459
Asia:				
Hong Kong	(3/)	109	9	348
Japan	2	436	1	56
Korea, Republic of	(3/)	377	--	--
Philippines	(3/)	20	--	--
Singapore	1	34	--	--
Taiwan	1	2,060	2	64
Thailand	(3/)	82	--	--
Other 7/	36	741	1	39
Total	40	3,860	13	507
Oceania, other 8/	1	103	6	219
Middle East, other 9/	3	1,640	(3/)	30
Africa, other 10/	2	482	9	51
Grand total	2,140	21,200	270	3,030

-- Zero

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.

3/ Less than 1/2 unit.

4/ Includes Barbados, Belize, Bermuda, British Virgin Islands, Costa Rica, the Domincan Republic, Giatemale, Honduras, Jamaica, Panama, and Saint Kitts and Nevis.

5/ Includes Brazil, Chile, Colombia, and Suriname.

6/ Includes Austria, Croatia, Finland, France, Greece, Ireland, Italy, Kazakhstan, Latvia, the Netherlands, Norway, Poland, Russia, and Switzerland.

7/ Includes Brunei, China, India, Indonesia, and Pakistan.

8/ Includes Australia and New Zealand.

9/ Includes Israel and Saudi Arabia.

10/ Includes Angola, Congo, Egypt, Equatorial Guinea, Nigeria, and South Africa.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF CONSTRUCTION SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country or territory	1999		2000	
	Quantity	C.i.f. value 2/	Quantity	C.i.f. value 2/
Antigua and Barbuda	21	258	45	488
Australia	1	754	15	2,270
Bahamas, The	92	611	111	448
Canada	1,320	12,000	1,620	15,500
China	3	1,140	109	1,310
Dominica	18	241	11	189
Dominican Republic	25	266	161	668
Japan	6	1,000	14	1,500
Martinique	6	59	10	102
Mexico	375	3,430	711	4,360
Netherlands Antilles	13	214	4	50
Norway	24	1,210	35	1,210
United Kingdom	2	448	2	1,390
Other 3/	9	2,750	12	3,770
Total	1,920	24,400	2,870	33,300

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongide carrier.

3/ Includes France, Germany, Israel, Malaysia (2000), New Zealand, the Philippines, South Africa, Spain, and Venezuela.

Source: U.S. Census Bureau.

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TABLE 14
RECYCLED ASPHALT AND CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY REGION 1/

Region/division	Recycled asphalt						Recycled concrete					
	1999			2000			1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Northeast:												
New England	160	$808	$5.05	283	$920	$3.25	95	$381	$4.01	190	$970	$5.11
Middle Atlantic	13	72	5.54	54	298	5.52	334	2,290	6.85 r/	407	2,310	5.68
Midwest:												
East North Central	1,350	4,580	3.40 r/	827	4,100	4.96	982	4,420	4.50	1,870	7,270	3.88
West North Central	1,200	5,760	4.79 r/	873	4,000	4.59	2,170	7,420	3.43 r/	2,100	7,910	3.76
South:												
South Atlantic	577	2,890	5.01	300	1,450	4.82	387	2,590	6.69	224	906	4.04
East South Central	224	682	3.04	231	888	3.84	--	--	--	--	--	--
West South Central	55	65	1.18	34	412	12.12	7	102	14.57	19	230	12.11
West:												
Mountain	728	2,940	4.04	761	3,000	3.95	256	1,170	4.57	259	1,130	4.35
Pacific	2,080 2/	9,430 2/	4.53 2/	1,370 2/	6,520 2/	4.76 2/	2,450 3/	10,200 3/	4.14 r/ 3/	2,130 3/	11,900 3/	5.57 3/
Total	6,400	27,200	4.26 r/	4,740	21,600	4.56	6,680	28,500	4.27	7,210	32,600	4.52

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Includes Alaska.
3/ Includes Hawaii.

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TABLE 15
RECYCLED ASPHALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (thousand metric tons)	1999 Value (thousands)	1999 Unit value	2000 Quantity (thousand metric tons)	2000 Value (thousands)	2000 Unit value
Alabama	30	$106	$3.53	--	--	--
Alaska	208	985	4.74	191	$919	$4.81
Arizona	W	W	4.13	76	196	2.58
California	1,700	7,590	4.47	987	4,500	4.56
Colorado	91	335	3.68	174	958	5.51
Connecticut	7	31	4.43	2	10	5.00
Florida	--	--	--	27	450	16.67
Georgia	W	W	7.86	W	W	6.11
Idaho	W	W	2.20	81	178	2.20
Illinois	24	34	1.42	21	75	3.57
Indiana	30	43	1.43	50	154	3.08
Iowa	34	200	5.88	20	77	3.85
Kansas	80	777	9.71	W	W	9.96
Louisiana	14	19	1.36	W	W	12.41
Maine	45	169	3.76	143	494	3.45
Massachusetts	37	168	4.54	115	259	2.25
Michigan	588	1,280	2.18	56	226	4.04
Minnesota	1,020	4,180	4.12	741	2,970	4.01
Mississippi	100	240	2.40	100	330	3.30
Montana	W	W	7.80	10	61	6.10
Nevada	32	112	3.50	65	289	4.45
New Hampshire	3	18	6.00	2	14	7.00
New Jersey	W	W	6.14	40	237	5.93
New Mexico	277	1,500	5.40	W	W	4.22
New York	7	29	4.14	15	61	4.07
North Carolina	236	974	4.13	140	528	3.77
North Dakota	32	261	8.16	W	W	5.41
Ohio	253	502	1.98	125	752	6.02
Oklahoma	W	W	1.10	W	W	5.00
Oregon	38	227	5.97	62	468	7.55
Rhode Island	W	W	6.41	9	80	8.89
South Carolina	90	385	4.28	45	237	5.27
South Dakota	43	344	8.00	41	313	7.63
Tennessee	W	W	3.49	W	W	4.23
Utah	172	446	2.59	W	W	3.01
Vermont	5	13	2.60	14	63	4.50
Virginia	71	111	1.56	69	116	1.68
Washington	139	627	4.51	128	623	4.87
Wisconsin	453	2,720	6.00	575	2,890	5.03
Wyoming	W	W	3.00	71	348	4.90
Total	6,400	27,200	4.26 r/	4,740	21,600	4.56

r/ Revised. W Withheld to avoid disclosing company proprietary data, except unit value; included in "Total." -- Zero
1/ Data are rounded to no more than three significant digits, except unit value; may not add totals shown.

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TABLE 16
RECYCLED CONCRETE SOLD OR USED BY SAND AND GRAVEL PRODUCERS IN THE UNITED STATES, BY STATE

State	1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alaska	--	--	--	W	W	$5.33
Arizona	W	W	$16.60	--	--	--
California	2,200	$9,070	4.11	1,910	$10,800	5.67
Colorado	76	286	3.76	121	528	4.36
Connecticut	17	80	4.71	2	9	4.50
Florida	--	--	--	18	60	3.33
Georgia	W	W	7.61	--	--	--
Hawaii	4	27	6.75	4	31	7.75
Idaho	W	W	4.50	W	W	1.50
Illinois	134	748	5.58	211	1,080	5.10
Indiana	109	418	3.56	20	33	1.65
Iowa	87	585	6.72	109	711	6.52
Kansas	5	83	16.60	5	45	9.00
Louisiana	--	--	--	W	W	8.73
Maine	10	37	3.70	W	W	3.60
Maryland	--	--	--	W	W	2.79
Massachusetts	48	205	4.27	110	533	4.85
Michigan	246	833	3.39	842	2,320	2.75
Minnesota	1,910	6,050	3.16	1,760	6,510	3.69
Montana	W	W	6.92	W	W	6.11
New Hampshire	2	12	6.00	46	214	4.65
New Jersey	W	W	2.44	74	476	6.43
New Mexico	W	W	5.26	W	W	5.84
New York	310	2,220	7.16	333	1,840	5.51
North Carolina	82	283	3.45	31	102	3.29
North Dakota	W	W	4.67	(2/)	1	4.51
Ohio	170	915	5.38	234	1,260	5.38
Oregon	42	211	5.02	33	235	7.12
Pennsylvania	W	W	3.29	--	--	--
Rhode Island	W	W	2.78	23	180	7.83
South Carolina	20	126	6.30	W	W	6.90
South Dakota	W	W	4.41	229	651	2.84
Texas	7	102	14.57	10	134	13.40
Utah	33	93	2.82	77	253	3.29
Vermont	9	22	2.44	W	W	2.67
Virginia	W	W	8.33	W	W	8.13
Washington	206	864	4.19	175	724	4.14
Wisconsin	323	1,500	4.66	566	2,580	4.56
Total	6,680	28,500	4.27	7,210	32,600	4.52

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Less than 1/2 unit.

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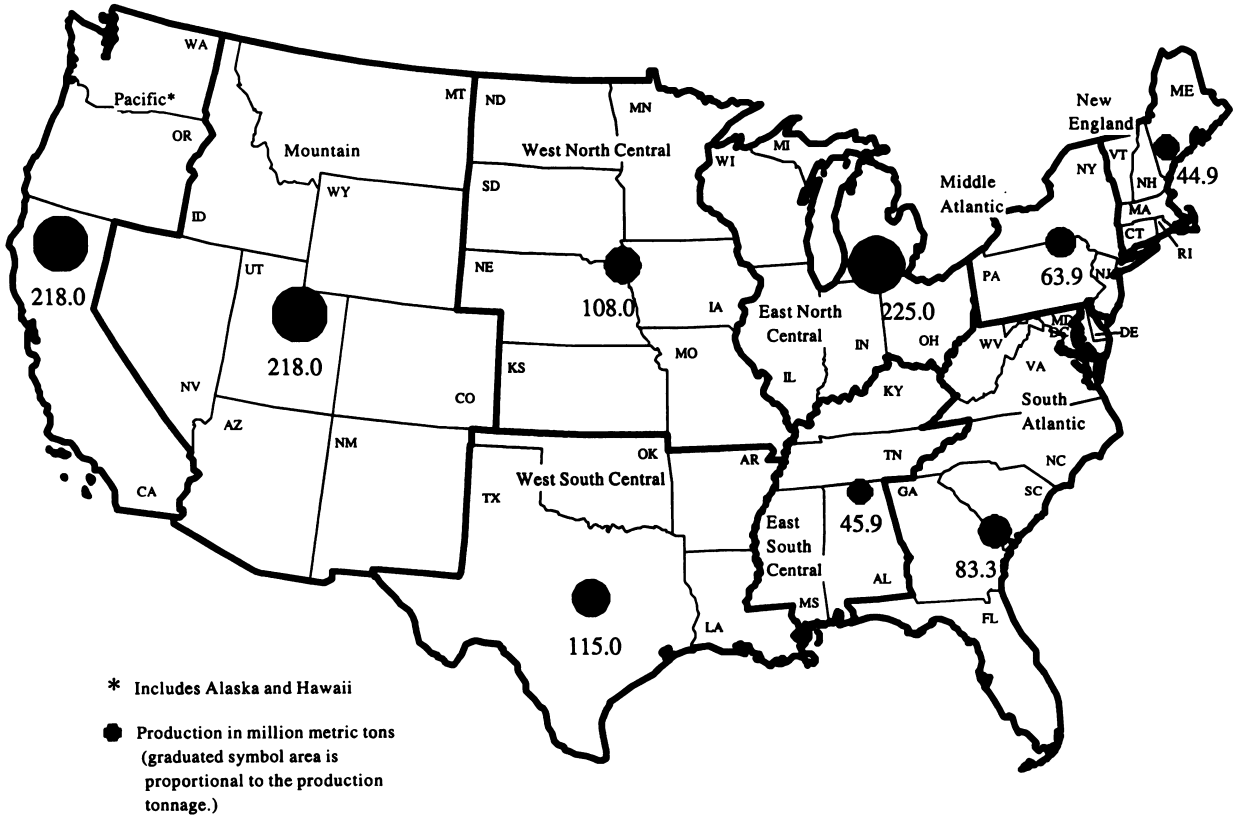
FIGURE 1
PRODUCTION OF CONSTRUCTION SAND AND GRAVEL IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION



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SELENIUM AND TELLURIUM

By Robert D. Brown, Jr.

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production tables were prepared by Ronald L. Hatch, lead international data coordinator.

Selenium and tellurium are byproduct metals usually associated with copper production. Primary selenium was produced domestically as a byproduct of copper refining in 2000; secondary (recycled) selenium was not produced. Five electrolytic copper refineries generated selenium-containing anode slimes. One of the refineries recovered commercial-grade selenium; one recovered a semirefined filter cake, which was shipped to Asia for further refining; and three exported anode slimes for refining. Domestic production increased in 2000.

Selenium use as a photoreceptor for plain-paper copiers has been decreasing in recent years and declined again in 2000 in favor of cheaper organic compounds. The distribution among other end-use sectors remained nearly the same, except that metallurgical applications increased. Estimates of end-use demand in 2000 are as follows: glass, 25%; metallurgical applications, 24%; miscellaneous chemical uses, 14%; photoreceptors, 10%; pigments, 8%; and other uses, including agricultural feed additives, 19%.

About 250 metric tons (t) of secondary selenium is produced every year worldwide. World refinery production of primary selenium (excluding U.S. production withheld to protect proprietary data) increased 4%, to 1,460 t; the largest producers, excluding the United States, in decreasing order of output, were Japan, Canada, Belgium, and Germany. These countries accounted for 86% of world refined selenium production in 2000.

World producers of refined tellurium were Canada, Japan, Peru, and the United States. Domestically, tellurium was recovered by one company from anode slimes generated in the electrolytic refining of copper and from soda slag skimmings generated in lead refining. Secondary tellurium was not produced domestically, but some scrap was exported for recycling. Production data reported to the U.S. Geological Survey are treated as company proprietary information. Domestic consumption is believed to have increased in 2000. About 55% of the tellurium was used as free-machining additives to steel. Other uses included catalysts, chemical uses, nonferrous alloys, photoreceptors, thermoelectric devices, and digital video discs.

Domestic Data Coverage

Domestic data are collected through a voluntary survey of U.S. selenium and tellurium producers. The production survey was sent to the two known domestic producers of selenium and the sole domestic producer of tellurium. All the companies responded to the survey. In order to protect proprietary interests of the companies, however, it is necessary to withhold the survey data from publication.

Production

Selenium.—Selenium was recovered from anode slimes generated in the electrolytic production of copper. Because selenium is a byproduct of copper production, its output cannot be easily adjusted to meet market conditions. Therefore, the selenium market is subject to supply and price fluctuations. Domestic production was higher than that in 1999. Only one domestic copper refinery recovered selenium—ASARCO Inc., Amarillo, TX. One producer exported semirefined selenium (90% selenium content) for toll-refining in Asia.

Three other companies generated selenium-containing slimes, but did not produce selenium. Selenium-containing slimes from these refineries were exported for processing.

Most domestic selenium was produced as commercial-grade metal, averaging a minimum of 99.5% selenium and available in various forms, including shot, lump, and powder or pigment-grade powder having a minimum 99.8% selenium content.

Hydromet Environmental Recovery Ltd. will accept waste material for the recovery of tin and selenium at its new plant scheduled to open during 2001 in Newman, IL. The plant expects to process selenium materials from both the copper refining and photocopy industries (American Metal Market, 2000b).

Tellurium.—Commercial-grade tellurium and tellurium dioxide were produced by Asarco, Amarillo, TX, mainly from copper anode slime but also from lead refinery skimmings. Asarco also produced high-purity tellurium (99.999% purity) and selenium (99.999% purity) and other high-purity metals and compounds at its plant in Denver, CO. Domestic tellurium production decreased in 2000, compared with that for 1999.

Consumption

Selenium.—Selenium demand by end use can be divided broadly into the following categories: glass manufacturing, electronics (including photoreceptor uses), agricultural uses, metallurgical applications, chemicals, and pigments.

In glass manufacturing, selenium is used principally as a decolorant in container glass and other soda-lime silica glasses. Under weak oxidizing conditions, the addition of selenium adds a pink color to the glass that combines with the green color imparted by ferrous ions to create a neutral grey color that has low perceptibility to the human eye. Selenium is also used to reduce solar heat transmission in architectural plate glass and to add red color to glass, such as that used in traffic lights. Glass manufacturing accounted for about 25% of the selenium market in 2000.

Metallurgical uses comprised an estimated 24% of the selenium market. It is estimated that more than one-half of the

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metallurgical selenium is used as an additive to steel, copper, and lead alloys to improve machinability and casting and forming properties. Several domestic producers of rolled steel bar produce selenium-bearing free-machining rod. Selenium-containing free-cutting steels, however, are generally cost competitive only when used with high-speed automatic machine tools.

Selenium (with bismuth) can replace lead in plumbing applications because they provide the same free-machining properties as lead without its negative environmental effects (King and Li, 1997). The Safe Drinking Water Act Amendments of 1996 (Public Law 104-182) requires that all pipes, fixtures, solders, and fluxes used for the installation or repair of facilities providing water for human consumption contain no lead after August 1998. Boosted by the goal set by Public Law 104-182, selenium use in plumbing continued to increase in 2000.

The Copper Development Association has changed the name of its alloys introduced in 1995 as SeBiLOY (containing selenium and bismuth) to Envirobrass to highlight the significant environmental and health benefits to manufacturers and consumers. Envirobrass I and II contain a mixture of bismuth and selenium substituted for lead in red brasses used for water meters, valves, and plumbing fixtures. A new alloy, Envirobrass III is a lead-free yellow brass for permanent mold casting (Payne, 2000).

A smaller amount of metallurgical selenium is used as an additive to low-antimony lead alloys forming the support grids of lead-acid storage batteries. The addition of 0.02% selenium by weight as a grain refiner improves the casting and mechanical properties of the alloy. Hybrid batteries, which employ low-antimony lead positive plates and lead-calcium negative plates, have been gaining in usage, thus increasing the demand for selenium.

Other uses, mainly agricultural, compose about 19% of the selenium market. Dietary supplements for livestock are the largest agricultural use. Selenium also may be added to fertilizer used in growing animal feed, a practice that is more prevalent outside the United States.

Electronics, which is a decreasing end-use market, accounted for 10% of selenium use. High-purity selenium compounds were used principally as photoreceptors on the drums of plain-paper copiers. Photoreceptors had been the largest single application for selenium during the 1970s and 1980s. Selenium compounds, however, are being replaced by organic photoreceptor compounds (OPC), which reportedly offer better performance and lower cost at printing speeds under 80 pages per minute and comparable cost and performance at faster printing speeds. OPCs also are free of the environmental concerns associated with the disposal of selenium compounds. Other electronic uses of selenium included rectifier and photoelectric applications.

Chemical uses of selenium, including industrial and pharmaceutical applications, accounted for about 14% of usage. Selenium is gaining greater recognition as a nutrient essential for human health; small but increasing quantities of selenium are used as human dietary supplements. As ongoing research verifies the apparent cancer-preventative properties of selenium, this application is increasing, but the low dosage requirement precludes it from becoming significant in terms of quantity consumed. The principal pharmaceutical use of selenium is in antidandruff shampoos. Miscellaneous industrial chemical uses include lubricants, rubber compounds, and catalysts.

In pigment applications, selenium is used to produce color changes in cadmium-sulfide-based pigments. Yellow cadmium pigment becomes more red as the selenium-to-sulfur ratio increases. Sulfoselenide red pigments have good heat stability and are used in ceramics and plastics as well as in paints, inks, and enamels. Because of the relatively high cost and the toxicity of cadmium-based pigments, their use is generally restricted to special applications requiring any combination of long life, brilliance, high thermal stability, or chemical resistance. Pigments accounted for about 8% of the selenium market.

Tellurium.—World demand for tellurium increased in 2000. The largest use for tellurium was as an additive to free-machining steel, about one-half of the market. Chemicals and catalyst usage made up about 25% of the market. Additives to nonferrous alloys accounted for slightly more than 10% of total use, and photoreceptor and thermoelectric applications accounted for slightly less than 10%. Other uses were about 5%.

As an alloying element in the production of free-machining low-carbon steels, additions of up to 0.1% tellurium, usually in conjunction with lead, greatly improve machinability. Similarly, the addition of tellurium to copper and other nonferrous alloys improves their machinability, strength, and corrosion resistance. Tellurium catalysts are used chiefly for the oxidation of organic compounds but are also used in hydrogenation, halogenation, and chlorination reactions. Tellurium dioxide is used as a curing and accelerating agent in rubber compounds.

Electronic semiconductor applications for high-purity tellurium include its use in thermoelectric and photoelectric devices and with selenium as a photoreceptor in plain-paper copiers. Mercury-cadmium-telluride is used as a sensing material for thermal imaging devices. Thermoelectric cooling devices, based on bismuth telluride semiconducting materials, are finding wider application in electronics and for some consumer products. These devices consist of a series of couples composed of different semiconducting materials which, when connected to a direct current, cause one side of the thermoelement to cool while the other side generates heat. The warm side is connected to a heat sink to dissipate the heat. Although thermoelectric coolers are still used more in military and electronic applications, such as the cooling of infrared detectors, integrated circuits, medical instrumentation, and laser diodes, their use in consumer products, such as portable food-and-beverage coolers, continued to increase. New applications include a germanium-antimony-tellurium compound used for optical storage on digital video discs (Metal Bulletin Monthly, 2000).

Prices

The domestic producer price for selenium averaged $3.84 per pound in 2000. Beginning the year at $2.78 per pound, the domestic producer price rose steadily to $4.30 per pound in

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early March, held firm for a month, and then retreated to $4.25 during April and May. In June, the price fell to $3.95 per pound and held steady for 4 months. During the last quarter of the year the price fell to $3.85 per pound in October, then to $3.25 per pound in mid-November where it remained for the rest of the year. The producer price for tellurium fell to $14 per pound by yearend, averaging about $14.50 for the year.

Trade

International trade is important in U.S. selenium and tellurium markets. In 2000, imports of selenium increased significantly (46%), while exports decreased markedly (65%). The United States was a net importer of selenium by 390 t including the selenium content of selenium dioxide compared with only 93 t in 1999. Canada, the Philippines, and the Republic of Korea (in order of decreasing quantity) were the leading foreign suppliers of selenium. They accounted for 86% of the imports of selenium metal to the United States in 2000. Imports of tellurium increased by 38% during the year. The leading suppliers were the United Kingdom, the Philippines, Belgium, and Canada. Data for tellurium exports were not available.

World Review

Overall, the world selenium market remained fairly well balanced, with a tendency toward excess supply replaced by steady production matched by strong increased demand from China (Metal Bulletin, 2000c). World production and consumption data for selenium and tellurium are limited. It is estimated that production of both selenium and tellurium, along with that of copper itself, increased in 2000 despite various interruptions, cutbacks, and closures in the copper industry. World production of the byproducts has been fairly steady over the past few years. Supply and demand have been in fairly close balance for several years. Better productivity has increased the possibility of oversupply, placing some downward pressure on prices. But cuts in copper production and the increased use of solvent extraction-electrowinning could shift the trend toward lower selenium and tellurium availability (Mining Journal, 2000b). Also, increased consumption of selenium in China, a net importer already, put upward pressure on prices for 2000 (Mining Journal, 2000a).

In the Philippines, the Philippine Associated Smelting and Refining Corp. announced plans for a substantial increase in copper production which will lead almost certainly to increases in selenium output (Mining Journal, 2001).

In Japan, total selenium demand is increasing in spite of lower consumption for photocopiers. Consumption is growing for glass, paint, pharmaceuticals, and shampoos. As the world's largest selenium supplier, Japan focuses on selenium export markets. Even so, as consumption increases, Japanese selenium exports have been dropping slightly every year since 1997. Considering the various worldwide production cutbacks, there is some concern over supply (Roskill's Letter from Japan, 2000).

In Belgium, Savi Alloys, N.V., sold its selenium production operations and will concentrate on bismuth and tellurium (Metal Bulletin, 2000b).

Current Research and Technology

Until recently, selenium has been one of the least celebrated human nutrients because selenium deficiencies are rare (in the United States) and its toxicity is a risk. The toxicity risk overshadowed the use of selenium as a human supplement, although the necessity of providing selenium in the diet of farm animals has been well established for years. In the past few years, research has revealed that human selenium supplementation may provide significant reductions in the occurrence rate of lung, prostate, and colorectal cancers. Medical tests have shown that, compared with a placebo group, cancer incidence among the patients receiving selenium was 46% lower for lung cancer, 48% lower for colorectal cancer, and 63% lower for prostate cancer (Clark and others, 1996).

Further testing and research is continuing and was reported on extensively in medical and popular health journals during 2000. The U.S. National Cancer Institute is funding the 12-year Selenium and Vitamin E Cancer Prevention Trial (SELECT) in the United States. The trial will seek to enroll more than 32,000 men to test the effect of selenium and vitamin E on the incidence rate of prostate cancer (Tracey, 2001). The Prevention of Cancer by Intervention with Selenium (PRECISE) trial in Europe will involve 33,000 men in three countries, Denmark, Sweden, and the United Kingdom. The SELECT and PRECISE trials are attempts to replicate the encouraging results of the 1996 trial on a larger scale. When too much selenium is taken by humans, it becomes toxic. The maximum safe level has been determined by several expert panels to be 400 to 450 micrograms per day form all sources, including diet and supplementation (Rayman, 2000).

In China, research has shown that variations in human selenium levels affect the incidence rate of esophageal and gastric cardia cancers. There was strong statistical evidence that increased selenium levels lowered the incidence of these cancers. Selenium levels were measured in about 1,000 patients with these cancers and in 1,000 subjects who did not have these cancers (Mark, 2000).

A new solar cell, based on a copper/indium/selenium compound has been developed in Germany. Cis-Solartechnik, GmbH, partly owned by Norddeutsche Affinerie AG, will continue development work on the new product, which is made mostly by deposition through galvanic processes onto a flexible copper strip. The new cell, with greater than 10% efficiency, is light in weight and extremely tough (American Metal Market, 2000a).

Evidence mounts that tellurium is not as toxic as generally thought. An 18 month old boy ingested tellurium dioxide in a hydrogen chloride solution. Although his serum tellurium levels were six times normal, there was no clinical evidence of tellurium toxicity (Higgins and others, 1999).

Outlook

Demand for selenium in photoreceptors, except where they are required for existing photocopiers, is likely to continue declining as the cost of substituting organic compounds decreases. A number of new uses have been developed, and they are beginning to affect the overall demand for selenium.

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Use as an additive to plumbing brasses, as part of the effort to use lead-free alloys, affords the greatest possibility for significant increases in demand.

As a byproduct of copper production, the outlook for selenium supply and price could be significantly affected by events in the copper industry (Metal Bulletin, 2001). When a copper plant closes or uses processes that do not generate anode slimes, the ultimate amount of selenium that can be produced is decreased (Platt's Metals Week, 2000). Thus, if current demand levels remain steady or increase, prices could continue to rise well above the lows that occurred in the past decade (Metal Bulletin, 2000a).

Chinese demand is still increasing, but there is no significant domestic production; consequently, China is dependent on imports, mostly from Japan. This growing import reliance suggests that Chinese producers may not be able to introduce low-cost supplies in the world selenium market when prices increase (Mining Journal, 2000b).

Further use of selenium in cancer prevention may eventually lead to profound public health benefits. However, this important application for selenium will not induce a large increase in demand for the metal because only small dosages of it would be necessary for effective therapy.

Tellurium supply and demand have remained in fairly close balance for a decade. Large increases are not foreseen in either consumption or production for the immediate future. The demand for high-purity tellurium for solar cells and electronic devices could increase and this would have a major impact on tellurium consumption.

References Cited

American Metal Market, 2000a, German company in copper project: American Metal Market, v. 108, no. 201, October 18, p. 6.

———2000b, Hydromet ready to take waste for metal recovery operations: American Metal Market, v. 108, no. 243, December 19, p. 10.

Clark, L.C., and others, 1996, Effect of selenium supplementation for cancer prevention: Journal of the American Medical Association, v. 276, no. 24, December 26, p. 1957-1963.

Higgins, T., Curry, S. and Ruha, A., 1999, Tellurium ingestion in an 18-month-old male: Journal of Toxicology, v. 37, no. 5, Abstract no. 103, August, p. 625.

King, M.G., and Li, Taie, 1997, Method for making machinable lead-free copper alloys with additive: U.S. Patent 5,614,038, March 25, 4 p.

Mark, S.D., 2000, Prospective study of serum selenium levels and incident esophageal and gastric cancers: Journal of the American Medical Association, v. 284, no. 24, December 27, p. 3108.

Metal Bulletin, 2000a, Market still cautiously optimistic on selenium: Metal Bulletin, no. 8442, January 17, p. 9.

——— 2000b, Savi sells off selenium: Metal Bulletin, no. 8451, February 17, p. 20.

———2000c, Selenium market sees mixed signals: Metal Bulletin, no. 8500, August 14, p. 8.

———2001, Interest revived in cadmium market: Metal Bulletin, no. 8859, March 19, p. 9.

Metal Bulletin Monthly, 2000, Who needs tellurium: Metal Bulletin Monthly, no. 355, July, p. 57.

Mining Journal, 2000a, Minor metals in May: Mining Journal, v. 334, no. 8586, June 9, p. 453.

——— 2000b, Selenium sparkles: Mining Journal, v. 334, no. 8568, February 4, p. 95.

———2001, Minor metals in December: Mining Journal, v. 336, no. 8615, January 5, p. 13.

Payne, R.M., 2000, US industry seen continuing record growth: American Metal Market, special report, v. 108, no. 32, February 17, p. 5A.

Platt's Metals Week, 2000, Prices of indium, selenium remain weak: Platt's Metals Week, v. 71, no. 48, November 27, p. 5.

Rayman, M.P., 2000, The importance of selenium to human health: The Lancet, v. 356, no. 9225, July 15, p. 233-244.

Roskill's Letter from Japan, 2000, Selenium-uncertainty over future supplies fuels price rises: Roskill's Letter from Japan, no. 291, November, p. 7-9.

Tracey, Elizabeth, 2001, Prostate cancer trial to test preventive agents: Family Practice News, v. 31, no. 2, January 15, p. 8.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Selenium. Ch. in Mineral Commodity Summaries, annual.
Selenium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Tellurium. Ch. in Mineral Commodity Summaries, annual.
Tellurium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

American Bureau of Metal Statistics; Nonferrous Metal Data.
American Metal Market.
JOM (formerly Journal of Metals).
Mining Journal (London).
Platt's Metals Week.
Selenium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Tellurium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT SELENIUM AND TELLURIUM STATISTICS 1/

(Kilograms of contained metal, unless otherwise specified)

	1996	1997	1998	1999	2000
Selenium:					
United States:					
Production, primary refined	379,000 2/	W	W	W	W
Shipments to consumers	400,000	W	W	W	W
Exports, metal and waste and scrap	322,000	127,000	151,000	233,000	82,100
Imports for consumption 3/	428,000	346,000	339,000	326,000	476,000
Apparent consumption, metal 4/	564,000	W	W	W	W
Dealers' price, average per pound, commercial grade 5/	$4.00	$2.94	$2.49	$2.50	$3.84
World, refinery production	2,250,000	1,710,000 r/	1,460,000	1,400,000 r/	1,460,000 e/
Tellurium:					
United States:					
Imports for consumption 6/	73,700	63,900	88,900	38,000	52,300
Producer price quote, yearend, commercial grade, per pound	$21.00	$19.00	$18.00	$15.00	$14.00

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Includes semirefined selenium produced by one company and exported for refining.

3/ Include unwrought waste and scrap and selenium dioxide.

4/ Calculated by using reported shipments, imports of selenium metal, and estimated exports of selenium metal, excluding scrap.

5/ Source: Metals Week. Calculated from published price ranges.

6/ Includes only wrought and waste and scrap.

TABLE 2
U.S. EXPORTS OF SELENIUM METAL AND WASTE AND SCRAP 1/

(Kilograms, contained selenium)

	1999		2000	
Country	Quantity	Value	Quantity	Value
Canada	3,740	$107,000	1,350	$37,100
Colombia	757	11,800	166	2,570
Costa Rica	363	3,020	935	8,090
Denmark	342	5,300	--	--
France	7,080	110,000	--	--
Hong Kong	--	--	2,320	36,000
Honduras	2,990	19,700	--	--
India	--	--	4,210	28,900
Italy	1,790	21,000	--	--
Japan	27,100	426,000	3,170	49,100
Korea, Republic of	--	--	1,000	12,000
Mexico	33,500	212,000	41,600	248,000
Panama	681	7,530	1,150	6,790
Philippines	122,000	561,000	11,400	29,700
Portugal	261	3,830	--	--
Taiwan	16,900	261,000	--	--
United Kingdom	11,300	107,000	14,800	124,000
Venezuela	4,110	44,100	--	--
Total	233,000	1,900,000	82,100	583,000

-- Zero.

1/ Data are rounded to no more than three significant digits: may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF SELENIUM 1/

(Kilograms, contained selenium)

Class and country	1999		2000	
	Quantity	Value	Quantity	Value
Unwrought waste and scrap:				
Australia	--	--	21,700	$86,200
Belgium	29,100	$1,160,000	14,800	388,000
Canada	99,000	833,000	237,000	783,000
Finland	5,240	19,200	1,110	4,740
Germany	1,950	55,800	3,680	118,000
Hong Kong	--	--	5,810	35,400
Japan	7,510	116,000	5,950	69,400
Korea, Republic of	6,950	30,900	29,100	183,000
Mexico	--	--	69	2,060
Netherlands	--	--	500	17,500
New Zealand	25	9,260	--	--
Philippines	140,000	762,000	121,000	914,000
Russia	904	27,100	1,300	9,750
United Kingdom	19,500	96,300	9,230	59,300
Total	311,000	3,110,000	452,000	2,670,000
Selenium dioxide: 2/				
Germany	15,700	157,000	23,600	180,000
Japan	--	--	709	6,250
United Kingdom	8	2,780	--	--
Total	15,700	160,000	24,300	186,000
Grand total	326,000	3,270,000	476,000	2,860,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Totals revised to 71% of original quantities and values.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM 1/

(Kilograms, gross weight)

Class and country	1999		2000	
	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:				
Belgium	5,110	$121,000	7,210	$143,000
Canada	9,390	592,000	5,140	630,000
China	17	33,800	1,240	71,200
Czech Republic	--	--	336	10,000
Ireland	--	--	316	14,600
Japan	521	105,000	9	8,100
Peru	1,990	17,200	4,030	29,100
Philippines	14,000	468,000	16,700	719,000
Russia	1	5,000	--	--
Ukraine	4	6,770	2	3,720
United Kingdom	6,940	95,200	17,200	170,000
Total	38,000	1,440,000	52,300	1,800,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms, contained selenium)

Country 3/	1996	1997	1998	1999	2000 e/
Belgium e/	250,000	250,000	200,000	200,000	200,000
Canada 4/	694,000	592,000	398,000	359,000 r/	350,000
Chile e/	50,000	49,500	49,000	49,000	49,000
Finland e/	42,000 r/	28,000	28,000 r/	26,000	26,000
Germany e/	115,000	115,000	100,000	100,000	100,000
India e/ 5/	11,500	11,500	11,500	11,500	11,500
Japan	588,186	546,372	549,615	546,292 r/	612,000 6/
Peru	12,602 r/	12,678 r/	18,006 r/	23,060 r/	23,000 p/
Philippines e/	40,000	40,000	40,000	40,000	40,000
Serbia and Montenegro e/	30,000	30,000	30,000	10,000	15,000
Sweden e/	20,000 r/	20,000	20,000	20,000	20,000
United States 7/	379,000	W	W	W	W
Zambia 8/	20,165	15,161	14,670	10,170 r/	9,820
Zimbabwe e/	2,000	1,000	400 r/	400 r/	415
Total	2,250,000	1,710,000 r/	1,460,000	1,400,000 r/	1,460,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper and/or refinery residues, but did not recover refined selenium from these materials indigenously were excluded to avoid double counting. Table includes data available through June 9, 2001.

3/ In addition to the countries listed, Australia produced refined selenium, but output was not reported; available information is inadequate to formulate reliable estimate of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

4/ Excludes selenium intermediates exported for refining.

5/ Data are for Indian fiscal year beginning April 1 of year stated.

6/ Reported figure.

7/ Includes production of semirefined selenium exported for further refining.

8/ Data are for year beginning April 1 of year stated. Gross weight, purity unknown.

TABLE 6
TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms, contained tellurium)

Country 3/	1996	1997	1998	1999	2000 e/
Canada 4/	59,000	59,000	62,000	64,000 r/	80,000
Japan	37,945	25,260	38,977 r/	35,272 r/	36,000
Peru	25,089	24,754	21,682 r/	16,610 r/	22,000
United States	W	W	W	W	W

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Estimated data are rounded to no more than three significant digits.

2/ Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper and/or refinery residues, but did not recover refined tellurium are excluded to avoid double counting. Table is not totaled because of exclusion of data from major world producers, notably the former Soviet Union and the United States. Table includes data available through June 9, 2001.

3/ In addition to the countries listed, Australia, Belgium, Chile, Germany, the Philippines, and the former Soviet Union are known to produce refined tellurium, but output is not reported; available information is inadequate for formulation of reliable estimates of output levels.

4/ Excludes selenium intermediates exported for refining.

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SILICA

By Thomas P. Dolley and Wallace P. Bolen

Domestic survey data and tables were prepared by Nicholas A. Muniz, Raymond I. Eldridge III, and Christine K. Pisut, statistical assistants, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

Four silica categories are covered in this report—industrial sand and gravel, quartz crystals, special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes tripoli and other fine-grained, porous silica materials that have similar properties and end uses, such as rottenstone. Certain silica and silicate materials, such as pumice and diatomite, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook.

Industrial Sand and Gravel

Total industrial sand and gravel production decreased by 1.7% to 28.4 million metric tons (Mt) in 2000 compared with that of 1999 (table 1). Compared with those of 1999, industrial sand production decreased by less than 1%, and gravel production decreased by about 14%. Exports decreased by less than 1% compared with those of 1999, and imports increased by 17% to 247,000 metric tons (t).

Industrial sand and gravel, often called "silica," "silica sand," and "quartz sand," includes sands and gravels with high silicon dioxide (SiO_2) content. These sands are used in glassmaking; for foundry, abrasive, and hydraulic fracturing (frac) applications; and for many other industrial uses. The specifications for each use vary, but silica resources for most uses are abundant. In almost all cases, silica mining uses open pit or dredging mining methods with standard mining equipment. Except for temporarily disturbing the immediate area while mining operations are active, sand and gravel mining usually has limited environmental impact.

The production decrease was minimal after several years of increasing demand for sand for many uses, including ceramics, chemicals, fillers (ground and whole grain), filtration, flat and specialty glass, hydraulic fracturing, recreational, and roofing granules. The demand for silica gravel, which was used for filtration and nonmetallurgical flux, experienced a significant decrease. Decreases in the production and sale of silica can be attributed in part to the decline of growth in the economy in 2000.

Legislation and Government Programs.—The regulation of respirable silica continued to concern miners and consumers of many minerals that contain crystalline silica, especially the industrial sand and gravel industry. One of the most important issues to have had an impact on the industrial minerals industry in recent times has been the question of crystalline silica and its effect on human health. Central to the ongoing and often heated debate has been the understanding and implementation of the measurements, the regulations, and the actions taken with regard to exposure to crystalline silica and, most significantly, the appreciation of its impact on the future of many industries (Industrial Minerals, 1998a).

Production.—Domestic production data for industrial sand and gravel were derived by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 69 producers with 154 operations known to produce industrial sand and gravel. Of the 154 surveyed operations, 130 (84%) were active, and 24 were idle. The USGS received responses from 112 operations, and their combined production represented about 78% of the U.S. total. Production for the 31 nonrespondents was estimated, usually based on previously reported information supplemented

Silica in the 20th Century

In 1902, 10 States reported production of "glass sand" for glassmaking, engine or traction sand, furnace sand, building sand, and miscellaneous uses. A total of 1.7 million metric tons valued at $1.42 million was reported. The commercial production of glass sand was reported from the States of Illinois, Indiana, Maryland, Massachusetts, Missouri, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. Besides silica sand, various silica stones were used as abrasive material. The value of grindstones produced in 1900 was $710,000, breaking the old record set in 1882. The production of infusorial earth and tripoli was 3,280 tons valued at $24,000. The production of millstones in 1900 was the largest since 1889, but the industry was still of insignificant importance compared with where it had been 20 years earlier. The substitution of the roller process for buhrstone in flour mills had practically eliminated the use of buhrstones for that purpose. The value of the oilstones and whetstones made in the United States in 1900 was $174,000, a decrease from 1899, when the largest production in the history of the industry had occurred.

In 2000, the United States was the largest producer and consumer of industrial silica, which included industrial sand and gravel, tripoli, special silica stone, and electronic- and optical-grade quartz crystal. U.S. production of industrial sand and gravel amounted to 28.4 million tons. U.S. exports of industrial sand and gravel totaled 1.66 million tons. Silica was arguably one of the most versatile industrial minerals in the 20th century. The most important uses of industrial silica were as glass sand, ceramics, and foundry sand. Other uses included metallurgical applications, abrasives, fillers, filtration, and hydraulic fracturing of rock formations to improve recovery in oil wells. Additionally, electronic-grade quartz crystal was used to accurately control frequency, in timers, and in filters in aerospace hardware, communications equipment, computers, consumer goods (e.g., clocks, games, television receivers, and toys), and navigation instruments.

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with man-hour reports from the U.S. Department of Labor's Mine Safety and Health Administration and information from State agencies.

The Midwest region (east-north-central and west-north-central divisions) continued to lead the Nation with about 40% of the 28.4 Mt of industrial sand and gravel produced in the United States, followed by the South (south Atlantic, east-south-central, and west-south-central divisions) with about 39% and the West (Pacific and mountain divisions) with 12% (table 2, figure 1).

The eight leading producing States, in descending order, were Illinois, Michigan, California, Wisconsin, Texas, New Jersey, North Carolina, and Oklahoma (table 3). Their combined production represented about 60% of the national total. Production remained relatively stable in all these States, except New Jersey and Texas, which had increased production from 1999 to 2000. Of the 36 States producing in 2000, 18 had increased production, 17 had decreased production, and 1 stayed about even compared with 1999. Mississippi, Texas, and New Jersey reported the largest increases, and Minnesota, Idaho, New York, and Arizona reported the largest decreases.

About 82% of the total industrial sand and gravel was produced by 51 operations, each with production of more than 200,000 tons per year (t/yr) (tables 4, 5). The 10 leading producers of industrial sand and gravel, in descending order, were Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Nugent Sand Co. Inc., Construction Aggregates Corp., Simplot Industries Inc., Little Six Corp., and Manley Brothers, Inc. Their combined production from 59 operations represented 76% of the U.S. total.

Unimin Corp. purchased the operation of Owen Illinois, Inc. of Amador County, CA, in July. The operation, near Ione, CA, processes silica from a kaolin/silica deposit, and most of the silica has traditionally been used for container glass manufacturing, although the amount of silica sold for other uses has been increasing. Unimin also operates a silica mine and plant near Byron, in Contra Costa County, CA.

In July, CSR America, Inc. purchased Florida Crushed Stone Co., which included Montgomery Sand Co. in Montgomery County, GA. The Mount Vernon, GA, operation produced both construction and industrial sand and gravel.

Oglebay Norton Specialty Minerals, Inc. purchased the Franklin Industrial Minerals operation in Cleveland County, NC. The plant is near Kings Mountain, NC, and processes silica from a weathered pegmatite that contains feldspar, kaolin, mica, and silica. Much of the sand is a feldspathic sand that is suitable for ceramics, glassmaking, and other uses in which alumina content is desirable.

Consumption.—Sand and gravel production reported by producers to the USGS was material sold to their customers or used by the companies. Stockpiled material is not reported until consumed or sold. Of the 28.4 Mt of industrial sand and gravel sold or used, about 38% was consumed as glassmaking sand and 22% as foundry sand (table 6). Other important uses were abrasive sand (4.6%) and frac sand (4.9%). Building products, a broad category that includes nonskid flooring, paints, putty, and stucco, consumed about 7.4% of industrial sand and gravel production.

Exploitable resources of industrial sand and gravel occur throughout the United States, and successful mining companies are responding to market locations, which have traditionally been in the Eastern United States. Occasionally, consuming industries are specifically located near a silica resource. Because of the abundance of silica deposits, locating near a silica resource has not always been a priority, although it certainly has been a consideration. The auto industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been greatly exploited in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2000, over 80% of foundry sand was produced in the Midwestern region.

Conversely, the glass industry had to locate plants where it could minimize the shipping distance of finished glass products (container, flat, etc.). Hence, glass plants were more evenly distributed. In 2000, 43% of glass sand was produced in the South; 30%, in the Midwest; 15%, in the West; and 12%, in the Northeast. To varying degrees, all silica production and sales are similarly influenced by the location of the consuming industries.

Some improvements in data collection affected the distribution by market segment for glass sand. Because of this improvement, some sand consumption formerly attributed to container and fiberglass production was placed in the flat and specialty segments. Therefore, although the increasing or decreasing trends in each market accurately reflects the growth in the various glass segments, the actual increase or decrease is likely not as large as the statistics portray.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was a little more than 38%. This percentage has remained stable compared with that of 1999. In 2000, sales to container glass manufacturers decreased by 8% compared with those of 1999. The amount of sand consumed for fiberglass production dropped by 4.8% compared with 1999.

In 2000, sales of sand for flat glass production increased by nearly 2.7% compared with those of 1999. In the South region, consumption for flat glass increased by 1.8%, and in the Midwest region, there was a 1.6% decrease.

Specialty glass consists of many segments, but the largest portion of it is laboratory and lighting glass (light bulbs, fluorescent, etc.). Specialty laboratory glass also makes up part of the apparatus used in many segments of the electronics industry, including in the production of optical fiber and semiconductors.

The U.S. fiberglass industry consists of four major insulation manufacturers and six major textile producers. Continuous glass fiber specifications are very strict. Batch grain-size control is very important, so ground silica (ultrafine powder) is used. Iron, potassium, and sodium oxide content is tightly controlled. The raw mix is fused at 1,600° C and then passed through platinum bushings at 1,300° C. Various mineral wools are fabricated using basalt and diabase (rock wool), glass (glass wool), or blast furnace slag (slag wool) (Industrial Minerals, 1998c).

Silica is used in ceramics in whole grain and ground forms. Generally, whole-grain silica is used about 22% to 32% in the ceramic body of sanitaryware (sinks, toilets, urinals, etc.). Ground silica is used to decrease viscosity and the expansion coefficient in ceramic glazes and other ceramic applications. A typical glaze composition consists of about 25% quartz or silica. In 2000, about 278,000 t of ground silica was used in ceramic production.

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Advanced ceramics, such as silicon nitride and silicon carbide, represent a growing market for silica and silica-based chemicals. Silicon carbide is manufactured by cooking silica sand or crushed quartz and oil coke at 2,400° C in an electric furnace for several days; sawdust or rice husks are added to increase porosity. Silicon carbide's thermal conductivity and expansion coefficient make it especially useful in the refractory industry (Industrial Minerals, 1998c).

The production of industrial-grade silicon carbide was on the order of 800,000 t/yr. Applications for silicon carbide include wear parts, such as seal rings, slide bearings, shafts, and dynamic pressure, or composite bearings used in a variety of pumps. The global market for silicon nitride, which is based on powder use, is estimated to be 300,000 t/yr. Primary markets for hybrid bearings, which are based on these materials, are machine tool spindles, aerospace components, and instruments such as dental drills, vacuum systems, and gyroscopes. Other markets for silicon nitride include engine components and cutting tools (Ceramic Industry, 1998).

Silica is also used in plastics as an extender, filler, and reinforcer. Whole-grain and ground silica are used in filler-type applications. Ground silica is used to thicken liquid systems, to avoid plateout in polyvinyl chloride, as a thixotropic and flatting agent, and in many other filler applications. Other silica (whole grain and ground) uses include nonskid flooring, paints, putty, stucco, and other building product applications. Silica is also used in paint because it offers acid, scrubbing, and wear resistance. As segregated for this survey, consumption in 2000 of whole-grain filler was about 2.1 Mt and of ground silica for filler was 159,000 t.

Cristobalite, a high-temperature silica mineral, is made from quartz by heating quartz to above 1,470° C. It consists of small octahedral crystals, which aggregate into rounded particles. The crystal structure is more open than quartz, resulting in lower specific gravity. The major market for cristobalite is in the solid mold industry, but it is also used in ceramics, grinding products, reflective coatings, refractories, and traffic paints (Paint and Coatings Industry, 1997).

Sodium silicate, produced primarily by reacting sand and soda ash in a furnace, is one of the traditional chemicals made with silica sand. One of the forces driving the increased demand for sodium silicate is the zeolite industry, which uses sodium silicate in its synthetic zeolite production.

Potassium silicate is produced in a similar fashion to sodium silicate but uses potassium carbonate or potassium hydroxide. Potassium silicate is more expensive than sodium silicate and is used primarily in welding rods.

Specialty silicas are usually produced by means of chemical and thermal processing of natural silica, silicon metal, or as a byproduct of other mineral or chemical processing. Although the USGS does not specifically collect information for specialty silicas, consumption does affect natural silica sales. Specialty silicas and silanes (silica chemicals) include colloidal silicas, fumed silica, fused silica and quartz, organofunctional silanes, precipitated silica, silica gels, silicones, and ultra-high-purity silica. These silicas are used in a variety of industries and products, including abrasives, adhesives, beverages, catalysts, coatings, electronics, encapsulants, food, health care, optics, paper and packaging, plastics, refractories, rubber, sealants, specialty coatings, textiles, thermoplastics, wafer polishing, and water treatment.

Pyrogenic, or fumed, silica forms tridimensional polymers used as thixotropic agents and in silicons and silanes and is widely used as a coating agent for filler-grade calcium carbonate (Industrial Minerals, 1998d). In table 6, industrial sand and gravel that would find its way into these specialty silicas is most likely reported by the producers in the categories "Chemicals," "Silicon metal," and possibly "Glassmaking: specialty." In 2000, silica sales for chemical production were 723,000 t, a decrease of 4.6% compared with those of 1999. Reported sales of silica gravel for silicon and ferrosilicon production increased by about 7% in 2000 compared with those of 1999. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys.

Optical fiber production involves a series of highly sophisticated manufacturing methods. For the optical fiber, a glass core is required with a high refractive index, surrounded by glass with a lower refractive index. This problem has been solved by using several manufacturing methods, such as producing all the fiber with fused silica but doping its core with an element that increases the refractive index (Industrial Minerals, 1998c).

High-purity fused silica used by the electronics industry is typically at least 99.95% SiO_2 and has a very low expansion coefficient, high electromagnetic radiation transparency, and good insulation properties.

By reacting sodium silicate with hydrochloric acid, synthetic precipitated silica and silica gel are produced. Precipitated silica has been used increasingly in tires but more so in Europe than in the United States. Through replacement of a proportion of carbon black with precipitated silica in the tread, the reinforcing action of the silica particles extends tire life (Industrial Minerals, 2000a). European consumers seem to prefer the "green" tires made with precipitated silica, and it is used in 70% to 80% of tires for passenger cars (Industrial Minerals, 2000b). Although these tires reportedly produce greater gas mileage, deficiencies in tread wear and higher costs to consumers and manufacturers account for their lack of popularity in the United States. Some new silicas, which aim to alleviate these problems, are being produced. If these problems are solved, then the "green" tire will probably become more popular in the United States. Precipitated silica is also used in battery separators and as a flatting agent in coatings, mainly high-solid, low-volatility organic compound coatings.

Transportation.—Of the total industrial sand and gravel produced, 61% was transported by truck from the plant to the site of first sale or use, down from 62% in 1999; 36% was transported by rail, up from 35% in 1999; 3%, by waterway; and 1% was not transported. Because most of the producers did not report shipping distances or cost per metric ton per mile, transportation cost data are not available.

Prices.—Compared with the average value of 1999, the average value, free on board (f.o.b.) plant, of U.S. industrial sand and gravel increased by 4.7% to $19.57 per metric ton in 2000 (table 6). The average unit values for industrial sand and industrial gravel were $19.87 per ton and $14.69 per ton, respectively. The average price for sand ranged from $6.50 per ton for metallurgical flux to $114.62 per ton for ground fillers. For gravel, prices ranged from $8.97 per ton for nonmetallurgical flux to $23.36 per ton for filtration. Producer prices reported to the USGS for silica commonly ranged from

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several dollars to hundreds of dollars per metric ton, and occasionally prices exceeded the $1,000-per-ton level. Nationally, ground sand used as fillers for rubber, paint, and putty had the highest value per metric ton ($114.62), followed by silica for swimming pool filters ($68.29), ground sand for ceramics ($51.94), ground sand for fiberglass ($43.05), ground sand for scouring cleansers ($37.47), refractory foundry sand ($36.11), abrasives for sawing and sanding ($35.56), and sand for hydraulic fracturing ($34.75).

Industrial sand and gravel price changes were mixed; some markets remained level, others had small increases or decreases, and still others had large increases or decreases. Although the silica was essentially the same, this situation was possible because most markets were independent of each other, and price competition was influenced by availability, regulations, health concerns, and competition from other materials.

By geographic region, the average value per ton of industrial sand and gravel was highest in the West ($21.38), followed by the South ($21.15), the Northeast ($20.60), and the Midwest ($17.29) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, the average value per ton of glass sand varied from $20.02 in the West to $14.98 in the Midwest. Tighter supplies and higher production costs in the West and much greater competition in the Midwest caused the difference in the cost of sand and gravel in these two regions.

Destination of Shipments.—Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section) and to which State or other location the material was shipped for consumption. Because some producers did not provide this information, their data were estimated or assigned to the "Destination unknown" category. In 2000, 9.7% of industrial sand and gravel shipped by producers was assigned to the "Destination unknown" category.

The States receiving the most industrial sand and gravel were, in descending order, Texas (7.1%), Illinois (6.7%), California (6.3%), Ohio (5.6%), Pennsylvania (4.9%), and Michigan (4.7%). With the exception of Alaska, all States received industrial sand and gravel. Producers reported sending at least 934,000 t of silica to Canada and 195,000 t to Mexico (table 7).

Foreign Trade.—Based on U.S. Census Bureau data, exports of industrial sand and gravel in 2000 decreased by 0.6% compared with the amount exported in 1999, and the associated value increased by about 35% (table 8). Most of the decrease in exports was attributable to decreased shipments to Mexico and Canada. For the fourth consecutive year, Mexico was the largest recipient of U.S. exports. Export distribution was as follows: 37% to Mexico, 28% to Asia, 19% to Canada, 11% to Europe, and the remainder to Africa, the Middle East, Oceania, and South America. The average price per ton of exports rose to $108 in 2000 from $80 in 1999. The increase in price reflected increased exports of higher grade silica, which averaged about $242 per ton, to Europe. Excluding Europe, other exports averaged $91 per ton in 2000.

The U.S. Census Bureau also reported that imports for consumption of industrial sand and gravel rose to 247,000 t, an increase of 17% from imports in 1999 (table 9). Silica imports vary greatly from year to year but are always rather insignificant in relation to total consumption. Canada supplied 73% of the silica imports for 2000, averaging about $12 per ton (including insurance and freight cost to the U.S. port). The total value of imports was $11.8 million, with an average of $48 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 96 Mt. The United States was the leading producer, followed in descending order by Germany, Austria, Spain, and France. Most countries in the world had some production and consumption of industrial sand and gravel, which is essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption (table 12).

Outlook.—The forecast range of total U.S. demand for industrial sand and gravel in 2001 is 28 to 30 Mt. Demand is expected to be about 29 Mt. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecasts made by analysts and producers in the various markets.

Sales of glass sand are expected to vary from market to market. Growth that might come in some segments, such as flat and specialty glass, will be offset by reductions in sales for container glass and possibly fiberglass. The trend towards the decreasing market share for container glass in the United States is expected to continue.

Total demand for glass sand is expected to grow slowly through 2001, probably to the range of 10 to 12 Mt.

The demand for foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling, though not clear, is thought to be increasing. Other materials or minerals compete with silica as foundry sand, but these other "sands" usually suffer a severe price disadvantage. On the basis of these factors, consumption of silica foundry sand in 2001 is expected to be 6.3 Mt, and the demand range is expected to be 6 to 7 Mt.

Frac sand sales declined by about 4% in 2000, compared with those of 1999. Domestic crude oil prices fluctuated during 2000, and domestic crude oil production was down from 1999 levels. On the basis of these factors, demand for frac sand is expected to remain about level during 2001. Demand for frac sand in 2001 is expected to be 1.4 Mt, with a range of 1.3 to 1.5 Mt.

For specialty silicas, the source of the silica is usually through the chemical and silicon metal categories, which will probably see better-than-average growth, in the 2%- to 4%-per-year range. This positive forecast would be tempered if the specialty silicas producers use a silica source other than industrial sand and gravel. Because the process for each type of silica is highly variable and certainly not well advertised, determining the natural source and the processing method for each of the silicas or silicates is difficult.

Specialty silicas are increasingly recognized as having reinforcing properties as fillers in various manufactured products. The average growth of specialty silicas in the United States is about 4% per year. Consumption in 2003 is expected

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to be 35,000 t of fumed and precipitated silica fillers (Industrial Minerals, 1998b). Another forecaster also projects 4% per year growth for specialty silicas, with fastest growth for fumed silica at 5%, precipitated and colloidal silica at 4%, and silica gel at 3.5% (Chemical Market Report, 1998).

The United States is the largest producer and consumer of silica sand and is self-sufficient in this commodity. Most of it is produced at premier deposits and near major markets in the Eastern United States. A significant amount of silica sand is also produced in the West and Southwest, mostly in California and Texas. Domestic production is expected to continue to meet more than 99% of demand well beyond 2001. Imports, mostly from Australia, Canada, and Europe, are expected to remain minor.

Because the unit price of silica sand is relatively low, except for a few end uses that require a high degree of processing, the location of a silica sand deposit in relation to the market is an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Several factors could affect supply and demand relations for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for foundry and glass sand. These substitutes, mainly polymers and ceramics, would likely increase the demand for ground silica, which is used as a filler in plastics; for glass fibers, which are used in reinforced plastics; and for silica (chemical, whole grain, or ground), which is used to manufacture ceramics. Also, increased efforts to reduce waste and to increase recycling could hinder demand for glass sand. With advances in high-tech materials and specialty silicas, however, consumption of silica sand may increase for fiberoptics and other silicon and glass compounds. Although developments could cause demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the more specialized sands.

Health concerns about the use of silica as an abrasive and stricter legislative and regulatory measures concerning silica exposure could reduce demand in many silica markets. The use of silica sand in the abrasive blast industry was being questioned as a health hazard, as marketers of competing materials, including garnet, olivine, and slags, pushed use of their "safer" abrasive media.

Development of more efficient mining and processing methods is expected to continue. This will encourage the development of lower grade silica sand deposits that are located closer to markets but are not presently mined. Such developments are expected to increase silica sand reserves.

Quartz Crystal

Electronic-grade quartz crystal is single-crystal silica with properties that make it uniquely useful for manufacturing accurate frequency controls, timers, and filters in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, communications equipment, computers, consumer goods (e.g., clocks, games, television receivers, and toys), and military and commercial navigational instruments. Such uses generate practically all demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used as lenses and windows in specialized devices, including some lasers.

Natural quartz crystal primarily was used in electronic and optical applications until 1971, when it was surpassed by cultured quartz crystal. The use of natural quartz crystal for carvings and other gemstone applications has continued. The use of quartz crystal for such applications is covered in the gemstones chapter of the USGS Minerals Yearbook.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained wide use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of the latter for a national stockpile began.

As of December 31, 2000, the National Defense Stockpile (NDS) contained about 105,309 kilograms (kg) of natural quartz crystal with a reported market value of about $696,000. The stockpile has 11 weight classes for natural quartz crystal ranging from 200 grams to more than 10,000 grams. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

As cultured quartz crystal displaced natural quartz crystal in most applications, the Federal Government continued to assess its stockpile goals for the latter material. In the latest reports on the inventory of stockpile material, no quartz crystals were designated for disposal. No natural quartz crystal was sold in 2000. Previously, only individual crystals in the NDS inventory that weighed 10 kg or more and could be used as seed material were sold. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced its output.

Quartz crystal, a form of crystalline silica, is also affected by the regulation of crystalline silica as discussed in the legislation and government programs subsection of the industrial sand and gravel section of this review.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2000, the industry consisted of three cultured quartz crystal producers. One of the growers responded to the annual survey, and the other two were estimated based on previously reported figures.

The following U.S. companies produced cultured quartz crystal during 2000: Sawyer Research Products Inc. of Eastlake, OH; Thermo Dynamics Corp. of Merriam, KS; and CTS Corp. of Carlisle, PA. P.R. Hoffman Material Processing Co. of Carlisle, PA, has the capacity to produce cultured quartz crystal but had no production in 2000. Sawyer and Thermo Dynamics produced crystal bars for domestic and foreign firms in the crystal device fabrication industry. CTS produced quartz crystal for internal consumption and domestic device fabricators.

The above-mentioned companies produced cultured quartz crystal by using a hydrothermal process in large pressure vessels known as autoclaves. Seed crystals (very thin crystals cut to exact dimensions) are mounted on racks and suspended in

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the upper growth region of the vessel. Lascas, a high-purity natural quartz feedstock, is loaded in an open-mesh wire basket that is placed in the bottom of the autoclave. A solution of sodium hydroxide or sodium carbonate (the mineralizer) with such additives as lithium salts and deionized or distilled water is used to fill the vessel from 75% to 85% of its volume. The bottom half of the growing vessel is heated to temperatures averaging between 350° C and 400° C; the temperature of the top portion is maintained at 5° C to 50° C less, depending upon the mineralizer used. At these temperatures, the solution expands and creates internal pressure between 700 and 2,100 kilograms per square centimeter. Under these conditions, the lascas dissolves to create a solution saturated with silica. Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach their desired size. The process normally takes from 30 to 60 days for a 1-inch-thick bar and longer for other types of crystal; at least one producer has made runs of about 180 days. The cultured crystals can be custom grown with specific properties.

Processing quartz crystal for various end uses is the same whether natural or cultured seed crystal is used. Producers, however, must avoid seed crystals with defects that could be passed on to new generations of cultured crystal. Natural quartz crystal is preferred as seed material to ensure that genetic defects will not be repeated in the succeeding generations.

Once produced, cultured crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness, electrodes are then attached, and the crystals are mounted in suitable holders. The final assembly, called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—In 2000, the USGS collected domestic consumption data for quartz crystal through a survey of 26 U.S. operations in 9 States that fabricate quartz crystal devices. These operations represented virtually all the domestic consumption. Of the 26 operations, 18 responded to the survey. Consumption for nonrespondents was estimated based on reports from previous years.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications requiring only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators also are used for many less demanding applications, such as providing timing signals for electronic circuits in automotive, consumer, and industrial products.

Cultured quartz is used almost exclusively by the crystal device industry because of the cost advantages. For resonator applications, raw cultured quartz must be cut into thin wafers oriented precisely with the raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining applications of the natural electronic-grade material is in pressure transducers used in deep wells.

Quartz wafers must be cut too thinly for practical use at very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than by wafer thickness, have become more prevalent at these higher frequencies. These structures are called surface acoustical wave devices.

Most optical applications use quartz in the fused form as silica glass. Relatively small quantities of cultured quartz crystal are used directly in optical applications. Quartz crystal also has uses involving birefringent filters, Brewster windows and prisms, normally polarized laser beams, quartz retardation plates (especially quartz wave plates), and tuning elements in laser optics.

Prices.—The average value of as-grown cultured quartz was estimated to be about $23 per kilogram in 2000. The average value of lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be about $143 per kilogram. As noted above, the estimated average market value of the unprocessed quartz crystal in the NDS in 2000 was about $7 per kilogram.

Foreign Trade.—The U.S. Department of Commerce (DOC), which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. Some lascas was imported from Germany in 2000, according to some consumers. Imports and exports of all electronic-grade quartz crystal are listed in table 11.

World Review.—Cultured quartz crystal production is concentrated in China, Japan, Russia, and the United States, with several companies producing crystal in each country. Production is less in Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, Eastern European countries, and the nations of the former Soviet Union are unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—Because the demand for quartz crystal devices will probably continue to grow, quartz crystal production will probably remain strong well into the future. The trend towards importing quartz could have a negative effect on domestic quartz growers. Growth of the consumer electronics market (e.g., automobiles, cellular telephones, electronic games, and personal computers), particularly in the United States, will continue to provide consumer outlets for domestic production. The growing global electronics market may require additional production capacity worldwide.

Special Silica Stone Products

Silica stone products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones,

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oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains. Information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook chapters.

Special silica stone, a crystalline silica, is also affected by the regulation of crystalline silica, as discussed in the legislation and government programs subsection of the industrial sand and gravel section of this review.

Production.—In response to a USGS production survey, 9 of 10 domestic firms reported that they quarried certain silica materials and manufactured silica stone products during 2000. Data for the remaining producer were estimated. Arkansas accounted for most of the value and quantity of production reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones. Tumbling-grinding media were produced in Wisconsin (table 10).

The industry has produced four main grades of Arkansas whetstone in recent years. The grades range from the high-quality black hard Arkansas stone down to Washita stone. In general, the black hard has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products is a combination of craft, household, industrial, and leisure uses. Major household uses include the sharpening of knives and other cutlery, such as lawn and garden tools, scissors, and shears. Leading industrial uses include the deburring of metal and plastic castings, the polishing of metal surfaces, and the sharpening and honing of cutting surfaces. Recreational uses include the sharpening of arrowheads, fish hooks, spear points, and sports knives. Craft applications include sharpening tools for engraving work, jewelry making, and wood carving. Also, silica stone files are used in the manufacture, modification, and repair of firearms.

Price.—The average value of crude material suitable for cutting into finished products was $286 per ton. The average value of stone products made from crude material was $14.76 per kilogram.

Foreign Trade.—In 2000, silica stone product exports had a value of about $6.4 million, unchanged from that of 1999. These exports were categorized as "hand sharpening or polishing stones" by the DOC. This category accounted for most of, if not all, the silica stone products exported in 2000.

In 2000, the value of imported silica stone products was at least $3.8 million, down by 39% compared with that of 1999. These imports were hand-sharpening or polishing stones, which accounted for most of or all of the imported silica stone products in 2000. A portion of the finished products that were imported may have been made from crude novaculite produced within the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

Tripoli

Tripoli, broadly defined, comprises extremely fine grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers, but particles as small as 0.1 to 0.2 micrometer are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending upon the percentage of iron oxide.

Tripoli, a crystalline silica, is also affected by the regulation of crystalline silica as discussed in the legislation and government programs subsection of the industrial sand and gravel section of this review.

Production.—In 2000, five U.S. firms were known to produce and process tripoli. American Tripoli Co. produced crude material in Ottawa County, OK, and finished material in Newton County, MO. Keystone Filler and Manufacturing Co. in Northumberland County, PA, processed rottenstone, a decomposed fine-grained siliceous shale purchased from local suppliers. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Harbison-Walker Refractories Co. Inc. in Hot Springs County, AR, produced crude and finished tripoli that is consumed in the production of refractory bricks and shapes. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. All these firms responded to the USGS survey.

Consumption.—The 2000 USGS annual survey of producers indicates that sales of processed tripoli decreased by 15% in quantity to 72,000 t with a value of $15.9 million (table 1).

Tripoli has unique applications as an abrasive owing to its hardness and because its grain structure lacks distinct edges and corners. It is a mild abrasive, making it suitable for use in toothpaste and tooth-polishing compounds, industrial soaps, and metal- and jewelry-polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 30 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2000, about 24% of tripoli output was used as an abrasive. The remainder was used as filler and extender in enamel, caulking compounds, paint, plastic, rubber, and in brake friction products, linings, refractories, and other products.

The primary use of tripoli today is as a filler and extender in paints. These applications may account for as much as 85% of the tripoli used as a filler and extender. In exterior latex paints, tripoli also aids in durability, flowability, leveling, and tint retention. In enamels, it eases application and improves sheen. The controlled grain and particle size of tripoli in paints improves dispersal and promotes a more uniform coating. Additionally, paints with tripoli resist chemical agents and wear better than those in which water-ground whitings and other softer or more reactive fillers are used.

Plastics, resins, and rubbers each account for about 5% of the tripoli used as a filler and extender. Tripoli is used extensively in plastics for electrical uses because of its dielectric characteristics and its effects on compression and flexibility properties. Its chemical resistance, resistance to salt spray, and weatherability also are important to its use in plastics. The physical properties of tripoli allow high loading in most compounds, but its abrasiveness results in high wear in extruding nozzles and molds. The same properties that make tripoli useful as a filler and extender in plastic make it valuable

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to the rubber and resin industries.

Price.—The average reported value of all tripoli sold or used in the United States was $221 per ton in 2000. The average reported value of abrasive tripoli sold or used in the United States during 2000 was $183 per ton; the average reported value of filler tripoli sold or used domestically was $265 per ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

References Cited

Ceramic Industry, 1998, Silicon-based ceramics: Ceramic Industry, v. 148, no. 6, June, p. 48.

Chemical Market Reporter, 1998, Silica market continues steady growth: Chemical Market Reporter, v. 254, no. 17, October 26, p. 3.

Industrial Minerals, 1998a, Crystalline silica: Industrial Minerals, no. 367, April, p. 109-117.

———1998b, Fillers are big business in plastics: Industrial Minerals, no. 375, December, p. 73

———1998c, Synthetic minerals—Part 1: Industrial Minerals, no. 371, August, p. 45-55.

———1998d, Synthetic minerals—Part 2: Industrial Minerals, no. 372, September, p. 57-67.

———2000a, Written in sand, the world of specialty silicas: Industrial Minerals, no. 390, March, p. 49-59.

———2000b, Nippon Silica supplies fuel-efficient tires: Industrial Minerals, no. 395, August, p. 11-12.

Paint and Coatings Industry, 1997, Cristobalite, a unique form of silica: Paint and Coatings Industry, v. 13, no. 8, August, p. 58-62.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Industrial Garnet. Mineral Industry Surveys, annual.
Manufactured Abrasives. Mineral Industry Surveys, annual.
Manufactured Abrasives. Mineral Industry Surveys, quarterly.
Pumice. Mineral Industry Surveys, annual.
Quartz Crystal. Ch. in Mineral Commodity Summaries, annual.
Silica Sand. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

A Stockpile Primer. U.S. Department of Defense, Directorate of Strategic Materials Management, August 1995.
Aggregates Manager.
Ceramics Industry.
Electronic Component News, monthly.
Electronic News, weekly.
Electronics, biweekly.
Engineering and Mining Journal.
Glass International.
Industrial Minerals.
Pit & Quarry.
Rock Products.
Sand and Gravel. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT U.S. SILICA STATISTICS 1/

		1996	1997	1998	1999	2000
Industrial sand and gravel: 2/						
Sold or used:						
Sand:						
Quantity	thousand metric tons	25,500	26,300	26,400	26,900	26,800
Value	thousands	$473,000	$485,000	$491,000	$510,000	$532,000
Gravel:						
Quantity	thousand metric tons	2,240	2,170	1,790	1,940	1,660
Value	thousands	$24,100	$26,300	$22,200	$28,400	$24,400
Total sold or used:						
Quantity	thousand metric tons	27,800	28,500	28,200	28,900	28,400
Value	thousands	$497,000	$511,000	$513,000	$538,000	$556,000
Exports:						
Quantity	thousand metric tons	1,430	980	2,400	1,670	1,660
Value	thousands	$113,000	$134,000	$148,000	$133,000	$179,000
Imports for consumption:						
Quantity	thousand metric tons	7	39	44	211	247
Value	thousands	$1,500	$3,200	$2,750	$5,590	$11,800
Processed tripoli: 3/						
Quantity	thousand metric tons	79,600	81,300	79,600	84,900	72,000
Value	thousands	$18,400	$16,400	$16,900	$20,200	$15,900
Special silica stone:						
Crude production:						
Quantity	metric tons	854	843	649	697	553
Value	thousands	$222	$224	$184	$183	$158
Sold or used:						
Quantity	metric tons	410	445	438	475	312
Value	thousands	$4,050	$2,560	$3,440	$3,060	$4,610
Electronic and optical-grade quartz crystals:						
Production:						
Mine	thousand kilograms	435	450	--	--	--
Cultured	do.	327	355	185	192	189

See footnotes at end of table.

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TABLE 1--Continued
SALIENT U.S. SILICA STATISTICS 1/

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Puerto Rico excluded from all industrial sand and gravel statistics.
3/ Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC REGION 1/

	1999				2000			
Geographic region	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percent of total	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percentage of total
Northeast:								
New England	155	1	2,790	1	104	(2/)	W	W
Middle Atlantic	2,380	8	46,800	9	2,400	8	51,500	9
Midwest:								
East north-central	10,100	35	164,000	30	10,100	35	170,000	31
West north-central	1,880	6	36,700	7	1,420	5	28,700	5
South:								
South Atlantic	4,200	15	87,800	16	4,270	15	92,400	17
East south-central	2,040	7	35,000	7	2,260	8	43,100	8
West south-central	4,360	15	87,700	16	4,440	16	96,400	17
West:								
Mountain	1,770	6	29,500	5	1,360	5	22,600	4
Pacific	2,040	7	48,400	9	2,090	7	51,300	9
Total	28,900	100	538,000	100	28,400	100	556,000	100

W Withheld to avoid disclosing company proprietary data; included with "Northeast: Middle Atlantic."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
State	Quantity	Value	Quantity	Value
Alabama	687	9,780	731	10,100
Arizona	268	3,720	W	W
Arkansas	W	W	W	W
California	1,790	43,700	1,810	45,200
Colorado	W	W	65	W
Florida	509	6,370	510	6,320
Georgia	612	11,100	651	12,500
Idaho	711	11,200	W	W
Illinois	4,460	71,100	4,430	71,600
Indiana	175	1,860	W	W
Iowa	W	W	29	W
Kansas	W	W	W	W
Louisiana	636	10,400	648	12,300
Maryland	W	W	W	W
Michigan	2,550	28,100	2,520	27,800
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Nebraska	W	W	W	W
Nevada	W	W	609	W
New Jersey	1,580	32,100	1,690	35,700
New Mexico	W	W	W	W
New York	W	W	W	W
North Carolina	1,470	27,300	1,480	28,300
North Dakota	W	W	1	W
Ohio	1,150	30,700	1,210	32,800
Oklahoma	1,470	30,900	1,480	30,700

See footnotes at end of table.

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TABLE 3--Continued
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	1999		2000	
	Quantity	Value	Quantity	Value
Pennsylvania	W	W	W	W
Rhode Island	W	W	104	W
South Carolina	769	18,400	755	18,600
Tennessee	W	W	W	W
Texas	1,620	37,100	1,750	45,200
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,730	32,000	1,790	36,200
Other	6,710	133,000	6,150	143,000
Total	28,900	538,000	28,400	556,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2000, BY SIZE OF OPERATION 1/

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	18	14	194	(2/)
25,000 to 49,999	12	9	384	1
50,000 to 99,999	28	22	1,900	7
100,000 to 199,999	21	16	2,700	9
200,000 to 299,999	12	9	2,580	9
300,000 to 399,999	8	6	2,540	9
400,000 to 499,999	10	8	3,680	13
500,000 to 599,999	8	6	4,450	16
600,000 to 699,999	6	5	3,550	12
700,000 and more	7	5	6,440	23
Total	130	100	28,400	100

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than one unit.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2000, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	1	--	--	--	--	1
Middle Atlantic	8	1	--	--	4	13
Midwest:						
East north-central	24	--	--	--	7	31
West north-central	4	--	--	--	6	10
South:						
South Atlantic	16	--	--	2	8	26
East south-central	7	--	--	--	4	11
West south-central	10	--	1	--	10	21
West:						
Mountain	7	--	--	--	--	7
Pacific	8	--	1	--	1	10
Total	85	1	2	2	40	130

-- Zero.

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TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2000, BY MAJOR END USE 1/

(Thousand metric tons and thousand dollars, unless otherwise specified)

Major use	Northeast			Midwest			South			West			U.S. total		
	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/	Quantity	Value	Value per ton 2/
Sand:															
Glassmaking:															
Containers	W	W	$18.21	1,340	14,100	$10.55	1,360	22,100	$16.28	W	W	$19.49	4,580	71,800	$15.69
Flat (plate and window)	W	W	16.90	1,230	14,500	11.78	2,240	35,600	15.88	W	W	16.65	4,190	62,100	14.82
Specialty	W	W	24.72	W	W	15.74	535	13,200	24.75	W	W	27.44	1,130	25,000	22.14
Fiberglass (unground)	19	225	11.67	W	W	14.54	117	1,990	16.97	W	W	17.67	519	7,820	15.07
Fiberglass (ground)	--	--	--	W	W	45.25	W	W	42.85	--	--	--	434	18,700	43.05
Foundry:															
Molding and core	W	W	18.58	5,030	67,600	13.43	776	12,600	16.18	W	W	22.30	6,160	87,000	14.11
Refractory	W	W	47.32	82	3,120	37.99	W	W	33.59	--	--	--	175	6,310	36.11
Metallurgical:															
Silicon carbide	--	--	--	W	W	11.82	--	--	--	--	--	--	W	W	11.82
Flux for metal smelting	--	--	--	--	--	--	W	W	5.83	W	W	6.61	W	W	6.50
Abrasives:															
Blasting	41	1,740	41.85	227	6,100	26.86	974	25,000	25.65	141	5,710	40.47	1,380	38,500	27.85
Scouring cleansers (ground)	W	W	58.08	W	W	36.25	W	W	108.12	--	--	--	W	W	37.47
Sawing and sanding	W	W	22.05	--	--	--	W	W	93.73	W	W	37.97	W	W	35.56
Chemicals (ground and unground)	W	W	20.01	W	W	14.05	328	9,130	27.83	W	W	20.11	723	15,400	21.31
Fillers (ground), rubber, paints, putty, etc.	W	W	44.04	110	8,680	78.67	W	W	236.64	W	W	28.54	159	18,200	114.62
Whole grain fillers/building products	227	7,030	30.99	488	14,600	29.82	936	17,400	18.59	458	14,100	30.66	2,110	53,000	25.14
Ceramic (ground), pottery, brick, tile, etc.	W	W	45.34	113	6,820	60.14	163	7,560	46.42	W	W	26.13	278	14,400	51.94
Filtration:															
Water (municipal, county, local, etc.)	W	W	49.99	W	W	41.19	166	3,150	18.95	114	5,060	44.24	369	12,200	32.95
Swimming pool, other	22	1,290	59.14	W	W	77.04	23	1,950	83.71	W	W	39.13	73	5,000	68.29
Petroleum industry:															
Hydraulic fracturing	W	W	34.13	848	28,600	33.73	W	W	36.33	W	W	38.09	1,370	47,500	34.75
Well packing and cementing	--	--	--	W	W	28.11	W	W	17.63	(3/)	36	46.59	W	W	26.34
Recreational:															
Golf course (greens and traps)	W	W	15.87	W	W	23.25	365	3,610	9.90	247	5,780	23.36	948	16,000	16.92
Baseball, volleyball, play sand, beaches	115	1,880	16.39	W	W	23.05	110	1,410	12.76	W	W	17.35	429	7,920	18.45
Traction (engine)	W	W	24.96	90	1,080	12.10	66	889	13.56	W	W	24.16	168	2,290	13.61
Roofing granules and fillers	24	573	23.94	W	W	17.75	119	2,170	18.33	W	W	20.91	196	3,800	19.40
Other (ground silica)	(4/)	(4/)	44.04	42	1,850	44.12	430	26,000	60.47	23	752	32.64	XX	XX	XX
Other (whole grain)	2,050	38,800	18.89	1,890	31,700	17.99	1,350	32,600	24.19	1,880	36,000	19.19	XX	XX	XX
Total or average	2,500	51,500	20.60	11,500	199,000	17.29	10,100	216,000	21.52	2,860	67,400	23.55	26,800	532,000	19.87
Gravel:															
Silicon, ferrosilicon	--	--	--	W	W	23.15	W	W	17.77	--	--	--	690	12,300	17.81
Filtration	(4/)	(4/)	70.42	W	W	11.74	50	1,530	30.46	W	W	30.59	157	3,660	23.36
Nonmetallurgical flux	--	--	--	W	W	16.54	--	--	--	W	W	8.82	347	3,110	8.97
Other uses, specified	(4/)	(4/)	10.87	(4/)	(4/)	12.02	860	14,100	16.34	594	6,480	10.91	XX	XX	XX
Total or average	(4/)	(4/)	25.30	(4/)	(4/)	12.02	910	15,600	17.12	594	6,480	10.91	1,660	24,400	14.69
Grand total or average	2,500	51,500	20.60	11,500	199,000	17.29	11,000	232,000	21.15	3,460	73,900	21.38	28,400	556,000	19.57

W Withheld to avoid disclosing company proprietary data; for sand, included with "Other (ground silica)" or "Other (whole grain);" for gravel, included with "Other uses, specified." XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Calculated using unrounded data.

3/ Less than one unit.

4/ Withheld to avoid disclosing company proprietary data; included with "Other (whole grain)."

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TABLE 7
INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION 1/

(Thousand metric tons)

Destination	1999	2000	Destination	1999	2000
States:			States--Continued:		
Alabama	761	899	New Jersey	1,010	870
Alaska	(2/)	--	New Mexico	67	67
Arizona	407	328	New York	570	451
Arkansas	63	127	North Carolina	954	789
California	2,290	1,780	North Dakota	9	47
Colorado	254	613	Ohio	1,580	1,600
Connecticut	92	92	Oklahoma	673	623
Delaware	13	11	Oregon	79	63
District of Columbia	(2/)	(2/)	Pennsylvania	1,410	1,390
Florida	507	450	Rhode Island	68	7
Georgia	791	915	South Carolina	257	618
Hawaii	(2/)	(2/)	South Dakota	5	92
Idaho	614	395	Tennessee	997	891
Illinois	1,600	1,900	Texas	2,080	2,020
Indiana	1,030	1,030	Utah	62	29
Iowa	391	258	Vermont	2	2
Kansas	373	446	Virginia	319	504
Kentucky	336	377	Washington	185	171
Louisiana	707	814	West Virginia	209	294
Maine	1	1	Wisconsin	826	1,020
Maryland	96	96	Wyoming	16	66
Massachusetts	73	16	Countries:		
Michigan	1,760	1,340	Canada	644	934
Minnesota	245	380	Mexico	97	195
Mississippi	167	183	Other foreign countries	29	66
Missouri	361	305	Other:		
Montana	31	34	Puerto Rico	(2/)	--
Nebraska	69	14	U.S. possessions and territories	(2/)	(2/)
Nevada	35	51	Destination unknown	3,670	2,750
New Hampshire	3	1	Total	28,900	28,400

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

TABLE 8
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

	1999		2000	
Country	Quantity	Value 2/	Quantity	Value 2/
North America:				
Bahamas, The	(3/)	90	14	330
Canada	360	26,600	319	30,400
Mexico	820	23,800	609	20,900
Panama	16	497	15	501
Other	5	695 r/	7	1,340
Total	1,200	51,600	964	53,400
South America:				
Argentina	5	1,190	8	1,500
Brazil	1	924	3	1,750
Colombia	1	293	2	470
Peru	2	220	8	388
Venezuela	15	1,040	11	1,270
Other	1	238	(3/)	325
Total	25	3,900	32	5,700
Europe:				
Belgium	10	2,780	26	2,800
Finland	6	776	1	1,750
France	106	3,100	54	4,830
Germany	26	11,000	27	14,500

See footnotes at end of table.

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TABLE 8--Continued
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Europe--Continued:				
Netherlands	13	7,100	33	8,720
Switzerland	(3/)	231	25	1,160
Turkey	(3/)	49	--	--
United Kingdom	4	2,200	4	4,350
Other	14	3,600 r/	12	5,970
Total	179	30,800	182	44,100
Asia:				
China	7	2,790	16	5,920
Indonesia	2	668	18	1,200
Japan	155	20,300	313	34,700
Korea, Republic of	5	3,700	12	4,230
Malaysia	14	573	31	1,290
Philippines	(3/)	205	14	488
Singapore	27	6,920	40	10,900
Taiwan	11	6,150	14	7,550
Thailand	21	690	4	915
Other	9 r/	640 r/	2	1,600
Total	251	42,600	464	68,800
Middle East and Africa:				
Egypt	(3/)	15	7	269
Israel	6	221	4	214
Oman	5	3,090	3	1,740
Other	(3/) r/	393 r/	(3/)	452
Total	12	3,720	14	2,670
Oceania:				
Australia	2	579	7	4,550
Other	(3/)	9	1	215
Total	2	588	8	4,770
Grand total	1,670	133,000	1,660	179,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ F.a.s. value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999		2000	
	Quantity	Value 2/	Quantity	Value 2/
Australia	6	1,000	50	3,620
Canada	111	2,100	181	2,120
Chile	--	--	2	255
China	(3/)	255	4	4,830
Germany	(3/)	232	(3/)	209
Japan	3	146	(3/)	159
Mexico	88	1,120	9	117
Sweden	1	502	--	--
Other	2	239 r/	1	493
Total	211	5,590	247	11,800

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ C.i.f. value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) incurred in bringing material from foreign country to alongside carrier.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 2000

Company and location	Type of operation	Product
B&C Abrasives, Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Blue Mountain Whetstone Co., Hot Springs, AR	do.	Do.
Buffalo Stone Corp., Hot Springs, AR	Tumbling and sizing novaculite	Metal finishing media deburring media.
Dan's Whetstone Co., Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do.	Quarry	Crude novaculite.
Eagle Mountain Whetstone Co., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	do.	Do.
The Kraemer Co., Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Norton Company Oilstones:		
Hot Springs, AR	do.	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Smith Abrasives, Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Taylor Made Crafts Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Pearcy, AR	Quarry	Crude novaculite.

TABLE 11
SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS 1/

(Thousand kilograms and thousand dollars)

	1996	1997	1998	1999	2000
Production:					
Mine	435	450	--	--	--
Cultured e/	327	355	185	192	189
Exports (cultured): 2/					
Quantity	89	74	63	90	74
Value	22,200	31,100	24,300	25,400	22,800
Imports (cultured): 2/					
Quantity	42	63	47	26	31
Value	9,480	11,700	12,200	11,000	14,300
Apparent consumption e/	280	343	169	128	146

e/ Estimated. -- Zero.
1/ Data are rounded to no more than three significant digits.
2/ Excludes mounted piezoelectric crystals.

TABLE 12
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999	2000
Argentina	244	257	260 e/	250 e/	250
Australia e/	2,500	2,500	2,500	2,500	2,500
Austria	6,012	6,000 r/ e/	6,329 r/	6,857 r/	6,800
Belgium e/	2,300	2,300	2,400	2,400	2,400
Bosnia and Herzegovina e/	50	50	50	50	50
Brazil e/	2,700	2,700	2,700	2,700	2,700
Bulgaria	832	557	893	900 e/	900
Cameroon e/	12	12	13	12	12
Canada	1,558	1,896	1,905	1,702 r/	1,946 p/ 4/
Chile e/	300	300	300	300	300
Croatia	44	98	50	50 e/	50
Cuba e/	300	300	300	300	300
Czech Republic	2,486	1,800	2,000	2,000 e/	2,000
Denmark (sales) e/	50	50	50	50	50
Ecuador	24	43	40 e/	40 e/	40
Egypt 5/	850 r/	505 r/	574 r/	600 r/ e/	600
Eritrea e/	1,481 4/	1,500	1,500	1,000	1,000

See footnotes at end of table.

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TABLE 12--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1996	1997	1998	1999	2000
Estonia e/	25	25	25	25	25
Ethiopia e/	6	7	7	7	7
Finland	31	30 e/	30 e/	73 r/	70
France e/	6,550	6,560 4/	6,500	6,500	6,500
Gambia	450 e/	452	303	270	250
Germany e/	5,503 4/	6,000 e/	6,000	7,000	7,000
Greece	87 r/	96	90	90 r/	90
Guatemala e/	47 4/	49	50	50	50
Hungary 6/	325	328	241	250	250
Iceland e/	4	4	4	4	4
India	1,534	1,400	1,265	1,300 e/	1,350
Indonesia	300 e/	636	293	300 e/	300
Iran e/ 7/	1,000	1,000	1,000	1,000	1,000
Ireland e/	6	5	5	5	5
Israel e/	225	225	225	225	225
Italy e/	2,950 4/	3,000	3,000	3,000	3,000
Jamaica	16	12	6 e/	6	6
Japan	3,557	3,306	3,049	2,764 r/	2,800
Kenya e/	13	13	13	12	12
Korea, Republic of	1,690	1,222	1,257	1,305	1,300
Latvia e/	50	50	50	50	50
Lithuania e/	33	30	30	30	30
Malaysia	1,168 r/	950 r/	473 r/	509 r/	500
Mexico	1,425	1,564	1,733	1,800 e/	1,800
Netherlands e/	24 r/	24 r/	5 r/	3 r/	5
New Caledonia e/	40	40	40	40	40
New Zealand	24	26	25 e/	25 e/	25
Norway	960	900 e/	1,000 e/	1,000 e/	1,000
Pakistan e/	165	165	122	130	162 4/
Panama e/	23	-- r/	-- r/	-- r/	--
Paraguay e/	10	10	10	10	10
Peru	1,672	1,631	1,600 e/	1,600 e/	1,600
Philippines	31 r/	21 r/	16 r/	64 r/	70 4/
Poland	137	290	236	250 e/	250
Portugal e/	5	5	5	5	5
Serbia and Montenegro	239	200	200	100 e/	100
Slovenia	210	210	200	200 e/	200
South Africa	2,168	2,439	2,273	2,163	2,100
Spain e/	5,300	5,800	6,200 r/	6,550 r/	6,600
Sweden e/	1,500	500	500	500	500
Thailand	447	516	324	350 r/ e/	350
Turkey	779	900	1,107	1,100 e/	1,100
United Kingdom e/	4,816 4/	4,800	4,800	4,000	4,000
United States (sold or used by producers)	27,800	28,500	28,200	28,900	28,400 4/
Venezuela	763	798	611	650 e/	650
Zimbabwe 8/	96	52	10	-- e/	--
Total	96,000 r/	96,000 r/	95,000 r/	96,000 r/	96,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ Table includes data available through July 2, 2001.

2/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, and China, among others, produce industrial sand, but current available information is not adequate to formulate estimates of production levels.

4/ Reported figure.

5/ Fiscal years beginning July 1 of that stated.

6/ For the reported volumetric quantity, see the U.S. Geological Survey Minerals Yearbook 1998, v. III.

7/ Fiscal years beginning March 21 of that stated.

8/ Includes rough and ground quartz as well as silica sand.

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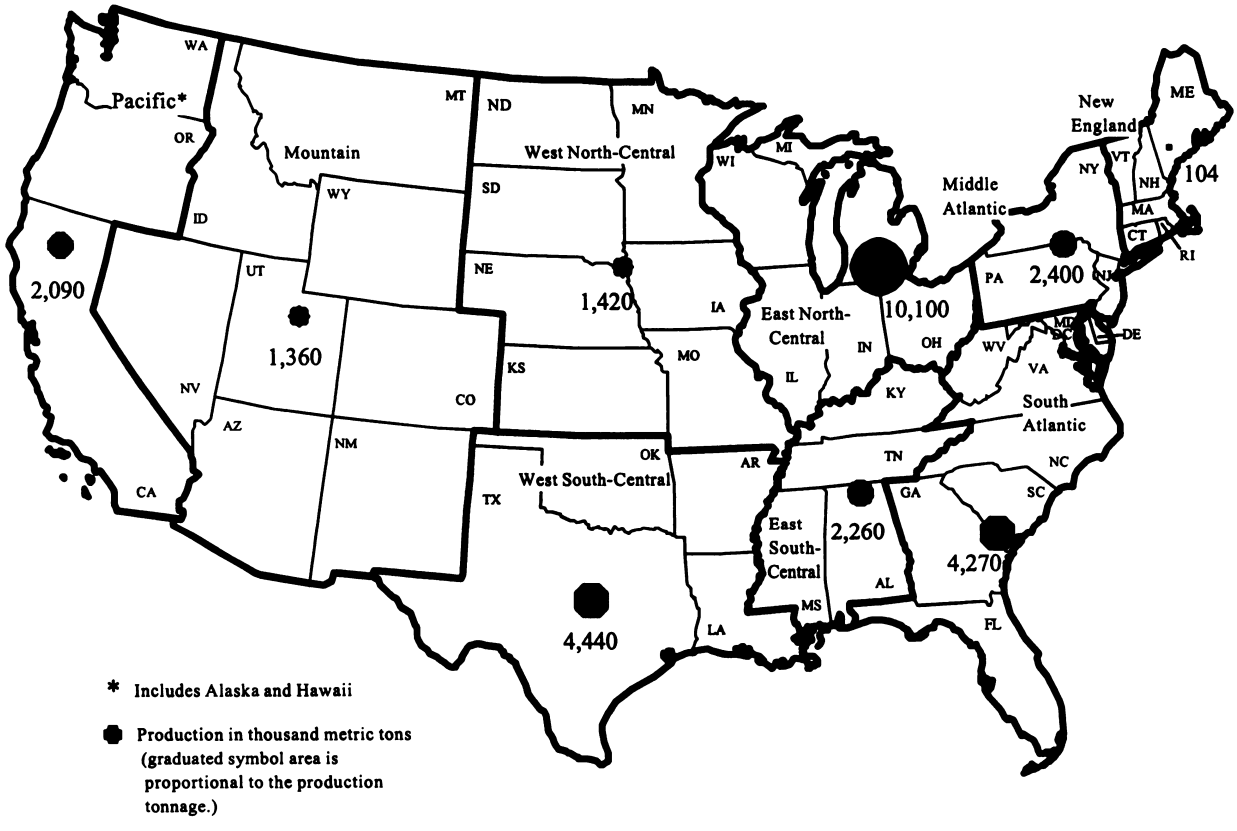
FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION



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SILICON

By Thomas S. Jones

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant.

Silicon (Si) is a light chemical element with metallic and nonmetallic characteristics. In nature, silicon combines with oxygen and other elements to form silicates. Silicon in the form of silicates constitutes more than 25% of the Earth's crust. Silica is a silicate consisting entirely of silicon and oxygen. Silica (SiO_2) as quartz or quartzite is used to produce silicon ferroalloys for the iron and steel industries, and silicon metal for the aluminum and chemical industries. Ferrosilicon and silicon metal are referred to by the approximate percentage of silicon contained in the material and the maximum amount of trace impurities present.

Almost all ferrosilicon products are consumed by the iron and steel industries. In terms of their nominal silicon contents, the two standard grades of ferrosilicon are 50% ferrosilicon and 75% ferrosilicon.

Silicon metal is used by the primary and secondary aluminum industries and the chemical industry, which uses it principally for silicones. Specifications for silicon metal used by the primary aluminum and chemical industries generally are more stringent than those for metal used by the secondary aluminum industry. In addition, the chemical industry requires that the metal be ground into a fine powder rather than the lump form used by the aluminum industry. Silicon metal that is refined into semiconductor-grade metal for use in making computer chips is crucial to modern technology, but the quantity is less than 5% of total silicon metal demand (Roskill's Letter from Japan, 2000). This report contains no information about this highest purity silicon except as it appears in the foreign trade statistics.

For 2000, an overall domestic silicon production of 367,000 metric tons (t) of contained silicon was the least since 1993. Decreases in production and shipments were the most notable in the ferrosilicon category of 56% to 95% silicon content (nominal 75% ferrosilicon), for which the declines were about 30%. On the basis of contained silicon, overall U.S. trade volumes rose by about 26% for imports and decreased by about 33% for exports. The trade category corresponding to nominal 75% ferrosilicon accounted for the majority of imports and increase in import volume. The export decline was associated mostly with silicon metal. The combination of decreased domestic production with increased net imports resulted in record high apparent consumption levels for ferrosilicon, silicon metal, and silicon materials overall; for silicon overall, the increase was 7% to 689,000 t. U.S. net import reliances for silicon materials equaled or exceeded any previous values, rising overall to 47% from 34%. Year-average dealer import prices for standard grades of ferrosilicon and silicon metal decreased for the fourth successive year, by a range of 8% to 12% for ferrosilicon and 6% for metal.

Legislation and Government Programs

The fine of $150,000 given in 1998 to the then-SKW Metals and Alloys Inc. (became CC Metals and Alloys, Inc., in 1999) for ferrosilicon price fixing was upheld in July by the presiding judge for the original criminal trial (Ryan's Notes, 2000c). The amount of the fine subsequently was appealed again by the U.S. Department of Justice (Ryan's Notes, 2000d). The fine being contended had been set by the U.S. District Court for the Western District of New York in Buffalo, NY.

Production

In terms of gross weight and in comparison with those of 1999, overall domestic gross production, net shipments, and stocks of silicon products decreased by about 13%, 16%, and 2%, respectively. The most pronounced year-to-year percentage declines were for the ferrosilicon category of 56% to 95% silicon content (nominal 75% ferrosilicon), for which

Silicon in the 20th Century

Usage of silicon as a ferroalloy in the production of steel and cast iron had been established prior to the turn of the century. Silvery pig iron, a low content silicon ferroalloy generally containing less than 20% silicon, already had been produced using blast furnaces in the 1890s. Electric furnace technology for producing silvery pig iron, ferroalloys with higher nominal silicon contents between 50% and 75%, and silicon metal began to be developed beginning about the start of the 20th century. Production and use of silicon ferroalloys received considerable impetus from World Wars I and II; use of ferrosilicon can be estimated to have paralleled domestic raw steel production, which increased approximately by a factor of 7.5 during the century.

The first significant use developed for silicon as a bulk element was for alloying with aluminum around 1920. After aluminum castings, the second largest use for silicon was production of silicones and related chemicals, which began developing in the 1930s and was accelerated during World War II. A third development, which began shortly after World War II, was usage of relatively small amounts of silicon in high-value, high purity forms in such key electronic devices as computer chips.

In 2000, U.S. production of the various grades of ferrosilicon plus elemental silicon (commonly referred to as metal) was about 400,000 metric tons of silicon content valued at approximately $400 million. Worldwide, in terms of gross weight, production was about 4 million metric tons for ferrosilicon and about 900,000 tons for silicon metal.

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production and shipments fell by about 30%. For silicon metal, production and shipments decreased by about 6% and 8%, respectively; stocks decreased only marginally. These comparisons are exclusive of silvery pig iron, statistics for which were not published to avoid disclosing proprietary data. In terms of silicon content and also exclusive of silvery pig iron, overall production of silicon materials was the least since 1993.

Domestic production data for silicon are derived from monthly and annual voluntary surveys and estimates for nonrespondents by the U.S. Geological Survey (USGS). The figures in table 2 represent 100% of the production and shipments from the operations listed in table 3 that are canvassed by means of the Silicon Alloys survey.

American Alloys Inc. stopped production of ferrosilicon and foundry alloys at its Graham, WV, plant after suddenly having declared Chapter 11 bankruptcy on January 26. Low prices and removal of antidumping duties on ferrosilicon from a number of foreign countries appeared to have been among the factors resulting in American Alloys' shutdown (Ryan's Notes, 2000a). This was the second time within 5 months that production was stopped at a domestic smelter where silicon ferroalloys or metal was being produced. After the shutdown, American Alloys sold material in inventory and manufacturing equipment (Platt's Metals Week, 2000; Ryan's Notes, 2000f).

Globe Metallurgical, Inc., with headquarters in Cleveland, OH, already a part owner of Norway's Fesil ASA, made an offer in August for all of the outstanding shares of Fesil, a producer of ferrosilicon and silicon metal (Ryan's Notes, 2000e). The offer was withdrawn early in November after it failed to interest holders of at least 90% of the outstanding shares (Metal Bulletin, 2000).

At Simcala, Inc. unionized hourly workers went on strike as of August 8. No immediate effect of the strike was apparent at the company's silicon metal plant at Mount Meigs, AL, a short distance east of Montgomery, as the striking workers were only a part of the total workforce (Ryan's Notes, 2000i). The strike continued for the rest of the year.

Principal elements in the cost of silicon and ferrosilicon production are the delivered costs of the ore (quartz or quartzite) and costs of energy, reductant coke or low ash coal, iron in the form of steel scrap (if required), and labor. Production of silicon metal and silicon-containing alloys is extremely power intensive and can require up to 14,000 kilowatthours of electric energy per metric ton of silicon contained in the final product (Dosaj, 1997, p. 1105). This high-energy demand can be offset somewhat by recovering heat energy from furnace offgases. Locations of ferrosilicon and silicon metal smelters are usually determined by balancing marketing costs against processing costs.

Silicon is not generally recovered from secondary sources. The only secondary possibility is recovery from metallic scrap, such as aluminum alloys, cast iron, and steel, from which recovery of contained silicon is incidental to that of the primary metal. Some silicon is recycled internally in smelters when fines or offgrade material are remelted.

Consumption

Ferrosilicon was used primarily as a deoxidizing and alloying agent in the production of iron and steel products. Silicon metal, which can be classified into metallurgical and chemical grades, was used by the aluminum industry in the production of cast and wrought products. It also served as the basic raw material in the manufacture of many chemical products and intermediates, such as silicones and silanes. Small quantities of silicon were processed into high-purity silicon for use in the semiconductor industry.

For 2000, total U.S. apparent consumption of silicon-containing ferroalloys and silicon metal was estimated to have increased by about 7% to 689,000 t of contained silicon. Also in terms of contained silicon, apparent consumption increased about 6% to 397,000 t for ferrosilicon and miscellaneous silicon alloys and somewhat more than 8% to 292,000 t for silicon metal. Increases in net imports that outweighed decreases in production resulted in the above three figures for apparent consumption that are thought to be the greatest ever. Still on the basis of silicon content, the share of total demand accounted for by ferrosilicon and miscellaneous silicon alloys remained at 58%. Table 4 presents data on U.S. reported consumption and stocks of silicon materials in 2000.

One supplier of ferroalloys has estimated that its shipments to iron foundries that consisted mostly of magnesium ferrosilicon, inoculants, and standard grades of ferrosilicon have advanced at a combined annual growth rate (CAGR) of 18% between 1992 and 1999 (Ryan's Notes, 2000k). Future growth in shipments to foundries appears likely to be slowed by plans by at least one domestic automobile manufacturer to replace iron by aluminum in engines (Wrigley, 2000).

Particularly in iron foundries, metallurgical-grade silicon carbide can substitute for ferrosilicon. Data on North American production and U.S. imports of silicon carbide were reported in the 2000 annual review of Manufactured Abrasives in the Mineral Industry Surveys series of the USGS and in the Manufactured Abrasives chapter of the 2000 Minerals Yearbook.

Consumption of ferrosilicon and silicon metal was estimated by CRU International Ltd. to have increased in 2000 for all areas of the Western World. In terms of contained silicon, the increase overall was from 1.73 million metric tons (Mt) to 1.83 Mt for ferrosilicon, and from a revised figure of 928,000 t to 1.03 Mt for silicon metal. The 2000 total for silicon metal consumption was the second consecutive alltime high. Areas having the largest year-to-year percentage increases were, for ferrosilicon, Japan and Other Asian countries, and for silicon metal, Japan and Western Europe. In decreasing order, Western Europe, Japan, and the United States accounted for 70% of the 2000 consumption total for ferrosilicon. Also in decreasing order, Western Europe, the United States, and Japan accounted for 84% of that for silicon metal (CRU Bulk Ferroalloys Monitor, 2001b).

For silicon wafers made from polycrystalline silicon, the CAGR between 1999 and 2003 has been forecast as about 10% (Hunter, 2000).

The CAGRs for silicone demand have been assessed as in excess of 10% for Southeast Asia, 4% to 6% for Western Europe and the United States, and 2% to 4% for Japan (Westervelt, 2000). Globally, the CAGR for silicones and silanes between 1995 and 1998 has been put at 6%. Consumption of silicones in the United States has been projected to have a CAGR of between 4% and 6% between 2000 and 2003 (Boswell, 2000). A healthy growth rate in demand also is forecast for silanes that function as coupling agents for fillers used in polymer composites. Sales of silane coupling agents worldwide currently amount to $600 million (Mack, 2000). Expansion of silicones operations overseas has

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been viewed as presenting a challenge to U.S. producers of silicon metal that serves as feedstock for silicones production. As an example, Dow Corning Corp.'s expansion in Wales has caused Dow Corning's Carrollton, KY, silicones plant to become a "swing" producer (Ryan's Notes, 2000b, g).

Microsilica (silica fume) is a potential byproduct from furnaces making silicon metal or ferrosilicon with a silicon content of at least 75%. It is obtained by capturing furnace offgases and finds use as a binder and filler in cements. The amount of microsilica dust currently being generated from silicon metal furnaces per year worldwide can be estimated to exceed 300,000 t (Kendall, 2000).

Prices

Demand for silicon ferroalloys and metal is determined in the short term less by their prices than by the level of activity in the steel, ferrous foundry, aluminum, and chemical industries. As a result, prices tend to vary widely with changes in demand and supply. The basis for U.S. prices of silicon materials was cents per pound of contained silicon.

Year-average import prices, as given by Platt's Metals Week or as calculated from Platt's weekly listings, were, in cents per pound, 35.4 for 75% ferrosilicon and 54.8 for silicon metal; these prices were about 12% and 6% lower, respectively, than those of 1999. In 2000, yearend prices were lower than those at the beginning of the year by about 3% for 75% ferrosilicon and 5% for silicon metal. For 50% ferrosilicon, beginning in January and continuing through the first week of September, Platt's listed only a price range of 43 to 47 cents per pound, which was the same as at the end of 1999. After the first week of September, Platt's discontinued this price listing. For the 8 months of 2000 this listing was in effect, the average of 45 cents per pound for 50% ferrosilicon was about 8% less than that for all of 1999. The ranges for North American transaction price for 50% ferrosilicon as given by Ryan's Notes were nearly the same as the range given by Platt's. At the point at which Platt's discontinued its listing, Ryan's Notes gave, in cents per pound, 43 to 48, and at yearend, 42 to 48.

The decline in year-average prices for silicon materials continued for the fourth successive year. The year-average price for silicon metal again was the least of any year since 1990. For 75% ferrosilicon and silicon metal, the pattern of price changes was similar for each—a rising trend until the first of April, a plateau, and then an irregular downward trend for the rest of the year. The price range for 75% ferrosilicon, in cents per pound, began the year at 34 to 36.5, slightly below the range of 34 to 37 at the end of 1999, reached and maintained a plateau for 3 weeks at a high point of 37 to 39, and ended the year at 33 to 35.25. For silicon metal, the price range, in cents per pound, began the year at 52 to 53, the same as at the end of 1999, held for 8 weeks at a high point of 58 to 59, and ended the year at 49 to 51.

Causative factors cited by CRU International Ltd. for prices of 75% ferrosilicon that CRU regarded as the lowest ever in real terms included foreign exchange rates, abolition of U.S. antidumping duties, and world oversupply. Prices in the United States that were higher than those elsewhere led naturally to an influx of imports (CRU Bulk Ferroalloys Monitor, 2000). Besides the strong U.S. dollar, a drop in demand from the aluminum industry contributed to the price slide for silicon metal (Ryan's Notes, 2000h).

Foreign Trade

Compared with those for 1999, total volumes of ferrosilicon and silicon metal decreased for exports (-33%) and increased for imports (+26%), on a content basis. The biggest year-to-year changes were for exports of silicon metal and imports of ferrosilicon. On a content basis, overall imports seemingly were the highest ever for ferrosilicon and silicon metal.

U.S. exports of ferrosilicon decreased by about 7% overall in gross weight but increased by about 5% in value. Australia, Canada, India, Japan, the Republic of Korea, Mexico, and the United Kingdom were the recipients of about 90% of total 2000 exports of ferrosilicon (table 5). Exports of silicon metal decreased by 50% in gross weight but increased by about 19% in value. Shipments of high-purity silicon of high unit value that contained more than 99.99% silicon rose 45% to account for about 94% of total value. Shipments in the category of "silicon, other," were only about one-third as great as in 1999. Combined shipments to Canada, Germany, Japan, and Mexico accounted for about 78% of total shipments. Those to Mexico were only about one-fifth those in 1999.

U.S. imports of silicon ferroalloys increased overall by 31% in gross weight and 21% in value compared with those for 1999. Import volumes increased for all significant categories except for ferrosilicon containing 55% to 80% silicon and more than 3% calcium. About 86% of total quantity and 81% of total value were accounted for by imports of nominally 75% ferrosilicon (ferrosilicon category of "55% to 80% silicon, other") (table 6). Reflecting the removal of antidumping and countervailing duties on ferrosilicon in late 1999, this category had the greatest year-to-year percentage increase in volume (39%). Norway continued as the leading overall source of ferrosilicon, although its share of the total fell to 32%.

Overall imports of silicon metal increased by about 14% in volume and 6% in value compared with those for 1999. Imports in the category of "silicon content from 99.00% to 99.99%," displaced those of high-value silicon metal that contained more than 99.99% silicon, in accounting for the largest share of total value, about 45% versus 40%, respectively. Among imports with a silicon content of from 99.00% to 99.99%, import volumes increased by 72% for those from Brazil and by 62% for those from South Africa. For the category of "silicon content less than 99%," imports from Saudi Arabia were only about one-tenth those of 1999. The year-to-year percentage changes in import volumes were -7% for "silicon content more than 99.99%," +36% for "silicon content from 99.00% to 99.99%," and -18% for "silicon, other."

The quantities of silicon metal imported from China were perceived by industry sources to be significantly greater than shown in table 6 because of shipments purportedly via another country, such as the more than 8,000 t of material reported as having come from the Republic of Korea (CRU Bulk Ferroalloys Monitor, 2001a).

For 2000, U.S. net import reliances were estimated to have risen from 38% to 53% for ferrosilicon and from 29% to 38% for silicon metal. The overall import reliance for silicon was estimated to have increased from 34% to 47%. These import reliances for silicon materials are believed to surpass any previous values except that the percentage for silicon metal equals that for 1994.

The general rates of duty that applied to U.S. imports during

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2000 were the same as in 1999. These were, on an ad valorem basis, 1.5% for standard 75% ferrosilicon, 1.1% for nominal 75% ferrosilicon that contains more than 3% calcium, free for magnesium ferrosilicon and most other ferrosilicon, and 5.3% or 5.5% for metal exclusive of the high-purity grade (U.S. International Trade Commission, 1999).

Effective with publication of Presidential Proclamation 7388 on December 21, the Generalized System of Preferences (GSP) Program was modified so as to grant duty-free status to certain products from sub-Saharan African countries. Ferrosilicon containing either 80% to 90% silicon or more than 90% silicon were among the products to which this form of GSP treatment now applied (Clinton, 2000). Silicon metal declarable under the import category that specifies a silicon content of less than 99% also had been a candidate for GSP treatment, but its tariff status was not changed (Ryan's Notes, 2000j).

The International Trade Administration (ITA) of the U.S. Department of Commerce published the results of its final or amended final antidumping duty administrative reviews for silicon metal from Argentina and Brazil.

For silicon metal from Argentina, for the period of review (POR) of September 1, 1997, through August 31, 1998, in a review that was specific only to Electrometalurgica Andina S.A.I.C. (Andina), it was found that no sales were made below normal value, so that no antidumping duties were assessed. Margins remained unchanged for other firms not covered in this review, as did the "all other" rate of 17.87% (International Trade Administration, 2000c). The ITA also rescinded its review for the POR of September 1, 1998, through August 31, 1999, for Andina because Andina made no shipments to the United States during this POR (International Trade Administration, 2000b).

For silicon metal from Brazil, for the POR of July 1, 1992, through June 30, 1993, the ITA amended again its final results for Companhia Brasileira Carbureto de Calcio (CBCC) and Eletrosilex Belo Horizonte to margins of 35.43% and 51.84%, respectively. These rates, however, did not change the cash deposit rates in effect for CBCC and Eletrosilex at the time of this amendment, as those rates continued to be based on the margins found in the most recently completed review (International Trade Administration, 2000e). For the POR of July 1, 1997, through June 30, 1998, the ITA determined a margin of 0.05% for CBCC; 18.87% for Eletrosilex; zero for Ligas de Aluminio, S.A., and Rima Industrial S/A; and 91.06% for "all others." The rate for CBCC was effectively zero because of its de minimis character of being less than 0.5% (International Trade Administration, 2000a).

The ITA also concluded expedited 5-year ("sunset") reviews of the antidumping duty orders on silicon metal from Argentina and China. The ITA found that revoking these orders was likely to lead to continuation or recurrence of dumping at weighted-average margins of 17.87% for Argentina and 139.49% for China (International Trade Administration, 2000d, f).

World Review[1]

Data on annual world production of ferrosilicon and silicon metal by country during 1996 to 2000 are given in Fenton [in press (a)]. World production of ferrosilicon was estimated to have been about 4.3 Mt in 2000 compared with a revised total of about 3.9 Mt in 1999. The major producers of ferrosilicon in 2000 were, in decreasing order, China, Russia, Norway, Ukraine, the United States, Brazil, Kazakhstan, France, and South Africa, and accounted for about 85% of total production. World production of silicon metal, excluding that from China, was estimated to have been about 720,000 t in 2000 compared with a revised total of about 700,000 t in 1999. China's production is believed to have been the world's largest, but data are lacking. Available information indicates that China's annual output of silicon metal in recent years was a minimum of 250,000 t (approximate export level) and, considering consumption within China, may have been in excess of 400,000 t. Other major producers of silicon metal in 2000 were, in decreasing order, the United States, Brazil, Norway, France, Russia, and South Africa; they accounted for about 82% of total production as listed in table 1.

Brazil.—In March, Dow Corning Corp. of the United States completed its acquisition of CBCC, which had an annual production capacity of 40,000 t for silicon metal and 20,000 t for ferrosilicon. Dow Corning planned to convert CBCC's facilities within a few years so as to give it the capability of producing 60,000 tons per year (t/yr) of silicon metal (Sissell, 2000). Subsequently, the structure of silicon metal production was changed further when Rima Industrial leased Eletrosilex' facilities having a silicon metal capability of 22,000 t/yr. Rima Industrial also was a producer of silicon as well as ferrosilicon.

Canada.—Bécancour Silicon Inc. described a new technology, termed the SKTEC process, by means of which either 75% ferrosilicon or silicon metal could be produced from the same furnace without any downtime in making a product change. This process has been in use continuously at Bécancour Silicon since late 1997 (Boisvert and Ksinsik, 2000).

China.—In 2000, China's exports of ferrosilicon rose to a total of about 490,000 t, and those of silicon metal totaled about 320,000 t. In 1999, exports of silicon metal exclusive of high-purity grades were 264,000 t, which was about 3% less than those of 1998; almost one-half of 1999 exports were reported to have gone to Japan.

A Government program for improving the efficiency and environmental performance of the country's electrometallurgical industries was underway. Production of ferrosilicon and silicon metal were among the materials to which this program applied, under which older and smaller furnaces were to be phased out.

France.—Invensil, formed in 1999 by combining the silicon metal activities of France's Pechiney Electrométallurgie (PEM) and South Africa's Samancor Ltd., enlarged its silicon capabilities in France and became wholly owned by Pechiney. In the first part of the year, a furnace at PEM's Château-Feuillet plant that was being used to produce calcium-silicon was converted to silicon metal, thus giving Invensil four production sites in France and adding 9,000 t to annual silicon production capacity. Late in the year, Pechiney acquired Samancor's minority interest in Invensil, thereby assuming full control of the Silicon Smelters plant at Pietersburg, South Africa.

India.—Late in the year, the Government recommended preliminary antidumping duties on imports of ferrosilicon from

[1]In a number of instances, discussions of the more significant developments during 2000 for specific countries were based on news items in trade journals, such as American Metal Market, Metal Bulletin, Platt's Metals Week, Ryan's Notes, and TEX Report. These items have not been acknowledged individually because the information they conveyed often was aggregated, possibly with that from other sources.

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China and Russia, but not those from Iran. Dumping margins were determined as about 43% for Chinese material and about 57% for Russian material. The Government's investigation was in response to a petition from domestic ferroalloy producers.

Norway.—Approximately 1 year after Fesil ASA had stopped production of silicon metal from three furnaces in the first half of 1999, production was restarted from the two furnaces that still were idle. These were one each at the Holla Metall and Lilleby Metall plants. In November, the affiliation of Switzerland's Gurta AG and the U.K.'s Tensil Ltd. took control of Fesil from Globe Metallurgical of the United States. This change occurred after Globe withdrew an offer by means of which it sought at least 90% of Fesil's shares.

In late 2000, AstroPower Inc. of the United States and Elkem ASA formed a project under which a low-cost process was to be developed for manufacturing solar-grade silicon at a jointly owned plant to be built in Norway. The new plant was to be managed by Elkem and its construction was to begin within 2 years.

South Africa.—As mentioned under France, the Silicon Smelters plant at Pietersburg for production of silicon metal that was a part of Invensil came fully under the control of France's Pechiney.

Silicon Chemicals.—In May, Dow Corning celebrated completion of an expansion of capability for methylchlorosilanes (MCS) at its Barry, Wales, plant. That plant's annual production capacity for these intermediates for production of silicones was approximately doubled to almost 200,000 t (Chemical Week, 2000a). Projects elsewhere for increasing capabilities for production of silicon chemicals included a 30% expansion by Rhodia SA at its plant at Roussillon, France, that would raise by 2002 its capacity for MCS to 200,000 t/yr and for siloxanes to 100,000 t/yr (Chemical Week, 2000c). Also in Europe, the GE Bayer Silicones joint venture between GE Silicones (50.1% ownership) and Bayer AG planned to double by 2002 the MCS production capacity at the Leverkusen plant to 300,000 t/yr (Chemical Week, 2000b). GE Silicones and Japan's Shin-Etsu Chemical Co., Ltd., formed a joint venture to build a plant at a site to be selected in Southeast Asia that would have a production capacity of about 70,000 t/yr for siloxanes (Chemical Week, 2000d).

Current Research and Technology

Investigations relating to the smelting of ferrosilicon and silicon included use of petrographic analysis for selection of coals and cokes to be used as reductants (Buø, Gray, and Patalsky, 2000), determination of material balances for trace elements (Myrhaug and Tveit, 2000; Tveit and Myrhaug, 2000), and modelling of alternating current arcs during typical operating conditions (Sœvarsdottir, Bakken, Sevastyanenko, and Gu, 2000).

Laboratory investigations relating to the behavior of silicon in steelmaking systems included study of factors affecting the efficiency of ferrosilicon in reducing chromium oxide from stainless steelmaking slags (Lee, Rhee, Song, and Klevan, 2000) and a determination that silicon additions appreciably reduce the rate of nitrogen dissolution in molten iron (Morita, Hirosumi, and Sano, 2000).

With regard to applications for high-purity silicon, a silane-based process for producing solar-grade silicon from metallurgical-grade silicon was evaluated in the laboratory (Block and Wagner, 2000), and the surface tension of molten silicon was measured under conditions of microgravity (Fujii and others, 2000).

For the A356 aluminum casting alloy (nominally 7% silicon, 0.4% magnesium) commonly used in structural parts of automobiles, the mechanical behavior of silicon particles in the alloy was studied at the high strain rates associated with crashes (Dighe, Gokhale, Horstemeyer, and Mosher, 2000).

Outlook

Demand for ferrosilicon follows trends in the iron and steel industries, for which the CAGRs typically have been in the range of 1% to 2%. Details of the outlook for the steel industry are discussed in the Outlook section of the annual review for 2000 for Iron and Steel (Fenton [in press (b)]. Raw steel production in 2000 increased in the United States by about 4%. Globally, the increase was even greater to give a new record for the world (Reynolds, 2001). Because the U.S. economic downturn in 2000 continued into 2001, however, in the immediate future the outlook was for a slump. The October 2000 midterm forecast for 2000 through 2005 of the International Iron and Steel Institute suggested a slow recovery, as the CAGR projected for the North American Free Trade Agreement countries was only 0.9% (Ian Christmas, Secretary General, International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth, accessed June 1, 2001, at URL http://www.worldsteelorg/trends_indicators/demand.html). For the foundry industry, declines in 2001 were foreseen for nearly all iron and steel castings categories. Longer term CAGRs for the 2000 through 2010 period were given as about 2% for iron castings overall and 0.8% for steel castings (Kirgin, 2001). For the world overall, silicon consumption as ferrosilicon during the first decade of the 21st century was not expected to have a CAGR greater than 1.5% to 2% (Roskill Information Services Ltd., 2000, p. 6).

Demand for silicon metal comes mainly from the aluminum and chemical industries. During the two decades leading up to 2000, Western World demand for silicon has had a CAGR of about 4.7%, and the chemicals sector of this demand has had a CAGR of nearly 7% (Linde, 2000). During the past 5 years, Western World silicon consumption has varied by region, having suffered declines in Asia and uneven growth in the United States (Roskill, 2000, p. 4). On the basis of a forecast for the foundry industry, demand for silicon by the aluminum castings industry can be expected to decline marginally in 2001, but to grow reasonably stronger thereafter until 2010 at an annual rate of 3.8% (Kirgin, 2001). This growth may not translate directly into increased demand for silicon because of an increase foreseen in recycling of automotive aluminum scrap. This adds to uncertainty as to whether Western World demand for silicon can continue to experience a CAGR of greater than 4% (Linde, 2000).

References Cited

Block, H.-D., and Wagner, G., 2000, Technical progress on the Bayer route to low cost solar grade silicon, *in* Øye, H.A., Rong, H.M., Nygaard, Lars, Schüssler, Gunnar, and Tuset, J.K., eds., Silicon for the chemical industry, 5th, Tromsø, Norway, May 29-June 2, 2000, Proceedings: Trondheim, Norwegian University of Science and Technology, p. 271-280.

Boisvert, R., and Ksinsik, D.D., 2000, The SKTEC process, *in* Øye, H.A.,

Digitized by Google

Rong, H.M., Nygaard, Lars, Schüssler, and Tuset, J.K., eds., Silicon for the chemical industry, 5th, Tromsø, Norway, May 25-June 2, 2000, Proceedings: Trondheim, Norwegian University of Science and Technology, p. 41-50.
Boswell, Clay, 2000, Silicone producers roll out investments: Chemical Market Reporter, v. 258, no. 24, December 11, p. FR24.
Buø, T.V., Gray, R.J., and Patalsky, R.M., 2000, Reactivity and petrography of cokes for ferrosilicon and silicon production: International Journal of Coal Geology, v. 4, nos. 1-4, May, p. 243-256.
Chemical Week, 2000a, Dow Corning opens U.K. plant, plans investment in Asia: Chemical Week, v. 162, no. 20, May 17, p. 20.
———2000b, GE Bayer Silicones to double silanes capacity: Chemical Week, v. 162, no. 15, April 12, p. 24.
———2000c, Rhodia plans rapid silicons [sic] expansion: Chemical Week, v. 162, no. 23, June 14, p. 17.
———2000d, Shin-Etsu, GE Silicones form Asian siloxanes venture: Chemical Week, v. 162, no. 38, October 11, p. 9.
CRU Bulk Ferroalloys Monitor, 2000, Ferrosilicon—Market still dogged by oversupply: CRU Bulk Ferroalloys Monitor, December 19, p. 4.
———2001a, Silicon metal—US anti-dumping duties retained: CRU Bulk Ferroalloys Monitor, January 23, p. 9.
———2001b, Supply/demand balances—Silicon alloys: CRU Bulk Ferroalloys Monitor, April 24, p. 8.
Clinton, W.J., 2000, Proclamation 7388—To modify duty-free treatment under the Generalized System of Preferences for sub-Saharan African countries and for other purposes: Federal Register, v. 65, no. 246, p. 80723-80732.
Dighe, M.D., Gokhale, A.M, Horstemeyer, M.F., and Mosher, D.A., 2000, Effect of strain rate on damage evolution in a cast Al-Si-Mg alloy: Metallurgical and Materials Transactions A, v. 31A, no. 7, July, p. 1725-1731.
Dosaj, Vishu, 1997, Silicon and silicon alloys—Chemical and metallurgical, *in* Kroschwitz, J.I., and Howe-Grant, Mary, eds., Kirk-Othmer encyclopedia of chemical technology (4th ed.): New York, John Wiley & Sons, v. 21, p. 1104-1122.
Fenton, M.D., [in press (a)], Ferroalloys, *in* Metals and minerals 2000: U.S. Geological Survey Minerals Yearbook, v. I.
———[in press (b)], Iron and steel, *in* Metals and minerals 2000: U.S. Geological Survey Minerals Yearbook, v. I.
Fujii, H., Matsumoto, T., Hata, N., Nakano, T., Kohno, M., and Nogi, K., 2000: Surface tension of molten silicon measured by the electromagnetic levitation method under microgravity: Metallurgical and Materials Transactions A, v. 31A, no. 6, June, p. 1585-1589.
Hunter, David, 2000, Silicon wafer makers head for a shakeout: Chemical Week, v. 162, no. 38, October 11, p. 31.
International Trade Administration, 2000a, Final results of antidumping duty administrative review—Silicon metal from Brazil: Federal Register, v. 65, no. 31, February 15, p. 7497-7507.
———2000b, Silicon metal from Argentina; antidumping duty administrative review—Rescission of antidumping duty administrative review: Federal Register, v. 65, no. 4, January 6, p. 758.
———2000c, Silicon metal from Argentina—Final results of antidumping duty administrative review: Federal Register, v. 65, no. 23, February 3, p. 5311-5312.
———2000d, Silicon metal from Argentina; final results of expedited sunset review of antidumping duty order: Federal Register, v. 65, no. 108, June 5, p. 35608-35609.
———2000e, Silicon metal from Brazil; amended final results of antidumping duty administrative review in accordance with court decision: Federal Register, v. 65, no. 100, May 23, p. 33297-33298.
———2000f, Silicon metal from the People's Republic of China; final results of expedited sunset review of antidumping duty order: Federal Register, v. 65, no. 108, June 5, p. 35609-35610.
Kendall, Tom, 2000, Written in sand—The world of speciality silicas: Industrial Minerals, no. 390, March, p. 49-59.
Kirgin, K.H., 2001, Demand for U.S. casting shipments to contract 4% in 2001: Modern Casting, v. 91, no. 1, p. 37-40.
Lee, Sang-Beom, Rhee, Chang-Hee, Song, Hyoseok, and Klevan, Ole-Svein, 2000, Reaction rate of ferro-silicon in the high Cr_2O_3 slag: Electric Furnace Conference 58th, Orlando, November 12-15, 2000, Proceedings, p. 1109-1121.
Linde, J.P. de, 2000, Silicon—A market in transition?, *in* Øye, H.A., Rong, H.M., Nygaard, Lars, Schüssler, Gunnar, and Tuset, J.K., eds., Silicon for the chemical industry, 5th, Trondheim, Norway, May 29-June 2, 2000, Proceedings: Trondheim, Norwegian University of Science and Technology, p. 87-95.
Mack, Helmut, 2000, Tailoring filler surfaces with silanes, *in* Keegan, Nina, ed., Industrial Minerals International Congress 2000, 14th, Denver, March 27-29, 2000, Proceedings: Worcester Park, United Kingdom, Industrial Minerals Information Ltd., p. 103-108.
Metal Bulletin, 2000, Globe withdraws Fesil takeover bid: Metal Bulletin, no. 8524, November 9, p. 7.
Morita, Kazuki, Hirosumi, Taro, and Sano, Nobuo, 2000, Effects of aluminum, silicon, and boron on the dissolution rate of nitrogen into molten iron: Metallurgical and Materials Transactions B, v. 31B, no. 5, October, p. 899-904.
Myrhaug, E.H., and Tveit, Halvard, 2000, Material balances of trace elements in the ferrosilicon and silicon processes: Electric Furnace Conference 58th, Orlando, November 12-15, 2000, Proceedings, p. 591-604.
Platt's Metals Week, 2000, Ferrosilicon producer American needs duties to restart: Platt's Metals Week, v. 71, no. 19, May 8, p. 8-9.
Reynolds, Vicki, 2001, IISI—Steel producers set world output record in 2000: American Metal Market, v. 103, no. 19, January 31, p. 3.
Roskill Information Services Ltd., 2000, The economics of silicon & ferrosilicon (10th ed.): London, Roskill Information Services Ltd., 216 p. plus appendix.
Roskill's Letter from Japan, 2000, Silicon metal—Japanese consumption forecast to rise by 9% in 2000: Roskill's Letter from Japan, no. 286, June, p. 15-17.
Ryan's Notes, 2000a, Chap. 11 for American Alloys; impact and causes debated: Ryan's Notes, v. 6, no. 5, January 31, p. 1.
———2000b, Decision on silicon GSP by end of year: Ryan's Notes, v. 6, no. 42, October 16, p. 2.
———2000c, Ferroalloy notes: Ryan's Notes, v. 6, no. 29, July 17, p. 4.
———2000d, Ferroalloy notes: Ryan's Notes, v. 6, no. 37, September 11, p. 4.
———2000e, Globe launches takeover bid for Fesil: Ryan's Notes, v. 6, no. 34, August 21, p. 3.
———2000f, Nucor tenders hold key to bulk market: Ryan's Notes, v. 6, no. 44, October 30, p. 1.
———2000g, Shopping begins for fourth-quarter silicon: Ryan's Notes, v. 6, no. 35, August 28, p. 2.
———2000h, Silicon cracks under falling demand: Ryan's Notes, v. 6, no. 29, September 25, p. 3.
———2000i, Simcala on strike; no effect anticipated: Ryan's Notes, v. 6, no. 33, August 14, p. 1.
———2000j, US silicon prices continue to creep up: Ryan's Notes, v. 6, no. 52, December 25, p. 3.
———2000k, US SiMn prices test the floor: Ryan's Notes, v. 6, no. 36, September 4, p. 2.
Sissell, Kara, 2000, Dow Corning acquires metals unit from Solvay: Chemical Week, v. 162, no. 12, March 22, p. 16.
Sœvarsdottir, G.A., Bakken, J.A., Sevastyanenko, V.G., and Gu, Liping, 2000, Modelling of AC arcs in submerged-arc furnaces for production of silicon and ferrosilicon: Electric Furnace Conference 58th, Orlando, November 12-15, 2000, Proceedings, p. 607-616.
Tveit, Halvard, and Myrhaug, E.H., 2000, Important sub-processes in the silicon process—The behavior of trace elements, *in* Øye, H.A., Rong, H.M., Nygaard, Lars, Schüssler, Gunnar, and Tuset, J.K., eds., Silicon for the chemical industry, 5th, Tromsø, Norway, May 29-June 2, 2000 Proceedings: Trondheim, Norwegian University of Science and Technology, p. 23-30.
U.S. International Trade Commission, 1999, Harmonized tariff schedule of the United States—2000: U.S. International Trade Commission Publication 3249, November 8, variously paginated and unpaginated.
Westervelt, Robert, 2000, Shin-Etsu, GE Silicones form Asian siloxanes venture: Chemical Week, v. 162, no. 38, October 11, p. 9.
Wrigley, Al, 2000, Iron yielding to aluminum in engines at GM: American Metal Market, v. 108, no. 161, August 21, p. 15.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Silicon. Ch. in Metal Prices in the United States Through 1998, 1999.
Silicon. Ch. in Mineral Commodity Summaries, annual.
Silicon. Ch. in Minerals Yearbook, annual.
Silicon. Mineral Industry Surveys, monthly.

Other

Advanced Materials & Processes.
American Metal Market.
Chemical and Engineering News.
Chemical Market Reporter.
Chemical Week.
Company news releases and reports.

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European Chemical News.
Ferro-Alloy Directory and Data Book, Metal Bulletin Books Ltd.
Industrial Minerals (London).
Metal Bulletin (London), semiweekly and monthly.
Platt's Metals Week.
Proceedings of ferroalloy conferences (INFACON, etc.)
Roskill Information Services Ltd. (London; last reported on silicon and ferrosilicon in 2000).
Roskill's Letter from Japan.
Ryan's Notes.
Silicon. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
TEX Report (Tokyo; daily issues and annual ferroalloy manual).
Ultra-high Purity Silicon for Infrared Detectors—A Material Perspective, U.S. Bureau of Mines Information Circular 9237, 1989.

TABLE 1
SALIENT SILICON STATISTICS 1/

(Thousand metric tons of silicon content, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production	412	430	429	423	367
Exports:					
Ferrosilicon	27	27	24	24	22
Silicon metal	17	22	23	37	19
Imports for consumption:					
Ferrosilicon	148	135	142	173	231
Silicon metal	79	121	99	113	130
Apparent consumption:					
Ferrosilicon	361	351	349	374	397
Silicon metal	233	277	267	269	292
Price, average, cents per pound Si: 2/					
Ferrosilicon, 50% Si	64.0	54.8	52.1	49.1	45.0
Ferrosilicon, 75% Si	62.2	48.0	43.1	40.2	35.4
Silicon metal	89.7	81.4	70.5	58.1	54.8
World:					
Production (gross weight): e/					
Ferrosilicon	4,300 r/	4,100	3,900	3,900 r/	4,300
Silicon metal	680 r/	690	690 r/	700 r/	720

e/ Estimated. r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Platt's Metals Week dealer import prices.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILICON ALLOYS AND METAL IN THE UNITED STATES 1/ 2/

(Metric tons, gross weight, unless otherwise specified)

	Silicon content (percentage)		1999	2000		
Material	Range	Typical	Producers' stocks December 31	Gross production 3/	Net shipments	Producers' stocks December 31
Ferrosilicon 4/	25-65 5/	48	46,800	229,000	151,000	48,300
Do.	56-95	76	30,400	100,000	98,500	27,000
Silicon metal (excluding semiconductor grades)	96-99	98	9,010	184,000	176,000	8,920

1/ Data are rounded to no more than three significant digits.
2/ Data for silvery pig iron (less than 25% silicon) withheld to avoid disclosing company proprietary data.
3/ Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.
4/ Includes miscellaneous silicon alloys, which formerly was listed separately.
5/ 25% to 55% for ferrosilicon; 32% to 65% for miscellaneous silicon alloys.

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TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND SILICON METAL IN THE UNITED STATES IN 2000

Producer	Plant location	Product 1/
American Alloys Inc.	New Haven, WV	FeSi.
Applied Industrial Minerals Corp.	Bridgeport, AL	Do.
CC Metals and Alloys, Inc.	Calvert City, KY	Do.
Elkem Metals Co.	Alloy, WV	FeSi and Si.
Globe Metallurgical, Inc.	Beverly, OH	Do.
Do.	Niagara Falls, NY	Si.
Do.	Selma, AL	Do.
Do.	Springfield, OR	Do.
Keokuk Ferro-Sil Inc.	Keokuk, IA	FeSi and silvery pig iron.
Simcala Inc.	Mount Meigs, AL	Si.

1/ FeSi, ferrosilicon; Si, silicon metal.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METALS IN THE UNITED STATE IN 2000 1/ 2/

(Metric tons, gross weight, unless otherwise specified)

End use	Silvery pig iron 3/	Ferrosilicon, 50% Si 4/	Ferrosilicon, 75% Si 5/	Silicon metal 6/	Miscellaneous silicon alloys 7/	Silicon carbide 8/
Steel:						
Carbon and high-strength, low-alloy	W	13,500	23,200	--	(9/)	(9/)
Stainless and heat-resisting	--	26	52,300	337	--	(9/)
Full alloy	--	(9/)	12,000	--	608	--
Electric and tool	--	(9/)	24,100	--	(9/)	(9/)
Unspecified	--	8,780	--	(10/)	1,720	6,120
Total	--	22,400	112,000	337	2,330	6,120
Cast irons	13,000	51,500	29,300	11	20,500	44,800
Superalloys	--	(10/)	(10/)	118	--	--
Alloys (excluding superalloys and alloy steel)	W	(10/)	(10/)	(10/)	--	(11/)
Miscellaneous and unspecified	--	2,360	527	236,000 12/	W	--
Grand total	13,000	76,200	142,000	237,000	22,800	50,900
Consumers' stocks, December 31	1,010	4,820	7,930	1,750	782	1,860

W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes U.S. Geological Survey estimates.
3/ Typically 18% silicon content but ranges between 5% to 24% silicon content.
4/ Typically 48% silicon content but ranges between 25% to 55% silicon content; includes briquets.
5/ Typically 76% silicon content but ranges between 56% to 95% silicon content; includes briquets.
6/ Typically 98% silicon content but ranges between 96% to 99% silicon content.
7/ Typically 48% silicon content. Primarily magnesium-ferrosilicon but also includes other silicon alloys.
8/ Typically 64% silicon content but ranges between 63% to 70% silicon content. Does not include silicon carbide for abrasive or refractory uses.
9/ Included with "Steel: Unspecified."
10/ Included with "Miscellaneous and unspecified."
11/ Included with "Cast irons."
12/ Primarily silicones, silanes, fumed silica, and other chemicals, plus aluminum alloys.

TABLE 5
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2000 1/

(Metric tons)

Country	Gorss weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Brazil	66	40	$52,900
Canada	4,520	2,710	3,320,000
Costa Rica	3	2	2,790
Jamaica	3	2	3,100
Korea, Republic of	3,010	1,810	2,470,000
Malaysia	29	19	45,600
Mexico	4,170	2,830	3,400,000
Taiwan	11	7	9,120
Total	11,800	7,420	9,290,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2000 1/

(Metric tons)

Country	Gorss weight	Contained weight	Value
Ferrosilicon--Continued:			
Other:			
Australia	3,450	1,720	2,990,000
Canada	6,970	3,480	4,570,000
China	1,790	896	1,580,000
India	3,900	1,890	5,920,000
Japan	3,760	1,160	7,080,000
Korea, Republic of	418	209	682,000
Mexico	1,380	680	1,800,000
Taiwan	660	323	1,090,000
United Kingdom	7,450	3,730	5,050,000
Venezuela	663	330	808,000
Other	1,040	524	1,060,000
Total	31,500	15,000	32,600,000
Grand total	43,300	22,400	41,900,000
Metal:			
More than 99.99% silicon:			
China	353	XX	$10,900,000
Denmark	56	XX	4,150,000
France	89	XX	2,660,000
Germany	183	XX	6,230,000
Italy	78	XX	6,370,000
Japan	3,880	XX	200,000,000
Korea, Republic of	666	XX	28,500,000
Malaysia	118	XX	25,000,000
Taiwan	202	XX	7,610,000
United Kingdom	55	XX	10,400,000
Other	269	XX	12,800,000
Total	5,950	5,950 e/	315,000,000
99.00% - 99.99% silicon:			
Belgium	33	33	46,500
China	88	88	125,000
France	241	239	337,000
Guatemala	10	10	13,600
Israel	18	18	25,300
Japan	184	182	255,000
Mexico	722	716	747,000
Norway	22	22	31,300
Singapore	17	17	49,300
United Kingdom	75	74	105,000
Other	49	48	113,000
Total	1,460	1,450	1,850,000
Other:			
Canada	5,250	5,100	5,510,000
China	263	255	571,000
Germany	1,310	1,270	1,820,000
Japan	703	683	1,260,000
Korea, Republic of	97	92	232,000
Malaysia	157	152	424,000
Mexico	2,470	2,400	5,240,000
Niger	96	93	127,000
Philippines, Republic of	71	69	93,800
Taiwan	603	585	984,000
Other	437	423	1,140,000
Total	11,500	11,100	17,400,000
Grand total	18,900	18,500	334,000,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2000 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
55% - 80% silicon, over 3% Ca:			
Argentina	119	64	$114,000
Brazil	131	80	132,000
France	249	162	403,000
Macedonia	5,910	4,460	3,050,000
United Kingdom	22	16	142,000
Total	6,430	4,780	3,840,000
55% - 80% silicon, other:			
Brazil	6,330	4,830	4,050,000
Canada	4,720	3,560	3,470,000
China	14,000	10,400	6,850,000
Iceland	16,000	12,000	7,460,000
Kazakhstan	61,700	46,900	29,400,000
Norway	88,900	67,800	52,500,000
Russia	15,700	11,100	7,720,000
South Africa	25,900	19,500	13,800,000
Ukraine	8,640	6,500	4,330,000
Venezuela	22,400	19,700	14,100,000
Other	10,900	5,980	13,800,000
Total	275,000	208,000	158,000,000
80% - 90% silicon, Russia	385	309	155,000
Over 90% silicon, Canada	35	35	45,700
Magnesium ferrosilicon:			
Argentina	1,570	713	1,200,000
Brazil	5,410	2,340	4,030,000
Canada	506	244	611,000
China	6,220	2,840	4,380,000
Germany	2	1	8,440
Japan	152	123	312,000
Netherlands	20	10	18,400
Norway	12,700	5,840	11,200,000
Total	26,600	12,100	21,700,000
Other:			
Argentina	5	2	12,400
Brazil	49	25	69,600
Canada	10,600	3,570	8,810,000
China	18	6	18,800
Germany	40	6	39,400
Japan	247	969	426,000
Norway	80	12	87,200
South Africa	2,310	990	584,000
United Kingdom	5	2	17,000
Ukraine	94	47	45,200
Total	13,400	5,630	10,100,000
Grand total	322,000	231,000	193,000,000
Metal:			
More than 99.99% silicon:			
Denmark	3	XX	$478,000
France	2	XX	51,100
Germany	506	XX	58,200,000
Italy	397	XX	19,900,000
Japan	499	XX	16,800,000
Korea, Republic of	141	XX	1,930,000
Sweden	6	XX	735,000
Switzerland	(2/)	XX	200,000
Taiwan	18	XX	365,000
United Kingdom	3	XX	453,000
Other	2	XX	131,000
Total	1,580	1,580 e/	99,200,000

See footnotes at end of table.

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TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2000 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Metal--Continued:			
99.00% - 99.99% silicon:			
Brazil	20,700	20,300	26,500,000
Canada	10,900	10,800	14,900,000
China	765	759	637,000
Germany	400	398	608,000
Korea, Republic of	6,510	6,440	5,680,000
Norway	2,990	2,970	4,480,000
Philippines, Republic of	201	199	204,000
Russia	11,300	11,100	12,900,000
99.00% - 99.99% silicon--Continued:			
Saudi Arabia	6,300	6,250	6,130,000
South Africa	33,700	33,000	38,200,000
Other	318	276	499,000
Total	94,100	92,500	111,000,000
Other:			
Canada	14,200	14,000	18,400,000
China	3,810	3,740	2,980,000
Germany	292	198	280,000
Japan	19	16	53,800
Korea, Republic of	1,720	1,690	1,510,000
Norway	83	18	224,000
Russia	11,400	11,200	10,900,000
Saudi Arabia	971	948	939,000
South Africa	4,180	3,630	3,150,000
United Kingdom	454	447	572,000
Other	16	12	38,700
Total	37,200	35,900	39,000,000
Grand total	133,000	130,000	249,000,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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SILVER

By Henry E. Hilliard

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

The difference between the high and low prices for silver in 2000 was less than $1.00 per troy ounce. Except for a brief period in February when the high for the year of $5.53 per ounce was reached, the silver price moved steadily downward in 2000 to an average of $5.00 per ounce, 5% lower than the 1999 level. This smaller movement in price occurred at a time when fabrication demand increased by 5% and more than 5,900 metric tons (t) of above ground stocks were needed to meet world demand. Lower demand in the photographic sector was more than offset by increased demand in jewelry and silverware and an 11% increase in industrial applications, where silver used in electrical and electronics were large growth areas.

According to the Silver Institute, world mine output of silver increased for the sixth consecutive year and at 18,900 t was the highest in history; secondary supplies at 5,600 t from old scrap were the second highest level in 20 years. U.S. Government stocks, the only silver used for the various coin and commemorative programs, decreased by 717 t to a level of 678 t in 2000. Stocks located in the principal exchanges increased 17% to 2,920 t in 2000.

Global reserves of silver in demonstrated resources from producing and nonproducing deposits at the end of 2000 were estimated to be 280,000 t by the U.S. Geological Survey (USGS). Reserves for the United States were estimated to be 33,000 t. The reserve base (reserves plus measured and indicated resources that are marginally economic and some of those resources that are currently subeconomic) for the five leading silver producing countries (Australia, Canada, Mexico, Peru, and the United States) were estimated to be about 232,000 t or 55% of the world total.

The USGS has issued a report on undiscovered gold, silver, copper, lead, and zinc deposits in the United States (U.S. Geological Survey, 2000, p. 10). The estimate of the amount of silver in undiscovered mineral deposits ranged from greater than 290,000 t at a 90% probability to greater than 660,000 t at a 10% probability. The mean estimate for silver in undiscovered deposits was 460,000 t. Total discovered silver resources in the United States were estimated to be 330,000 t.

Legislation and Government Programs

The major legislative action affecting silver was the passage of the Commodity Futures Modernization Act of 2000 (CFMA) on December 15. Contrary to the recommendation of the

Silver in the 20th Century

At the beginning of the 20th century, the major uses for silver, other than coinage, were for jewelry and sterlingware. Mexico and the United States were the leading producers. U.S. production averaged about 1,700 metric tons per year. During World War II, technological advances that influenced the outcome of the war were made in electronics and photography. After the war, this technology was used to develop new consumer products. As the demand for consumer goods increased, so did the demand for silver, and as a result, the market price for silver increased. The Silver Act of 1946 authorized the U.S. Treasury to purchase domestically mined silver at $0.905 per troy ounce and to sell its silver holdings at $0.910 per ounce.

In the late 1950s and early 1960s, a second component was added to the demand side of the supply-demand equation—the investor-speculator. Silver certificates, authorized by the Silver Purchase Act of 1934, were redeemable for silver held by the Treasury. At a market price above $1.29, a profit could be made by redeeming the silver certificates, receiving 0.77 ounce of silver from the Treasury, and then selling the silver. In addition, at a market price above $1.38, a profit could be made by melting U.S. circulating coinage for its silver content. Realizing that it could not supply industrial consumers with silver mint coinage and maintain a stock of silver for redemption of silver certificates, the Government began demonetizing silver. Public Law 88-36, which repealed the Silver Purchase Act of 1934 and authorized the printing of Federal Reserve Notes not redeemable in silver, was passed in mid-1963. The coinage act of 1965 eliminated the use of silver in dimes and quarters and reduced the silver content of half-dollars. In 1967, silver coins were withdrawn from circulation and holders of silver certificates were given 1 year to redeem the certificates for silver. With the ending of the relation between silver and the U.S. monetary system in 1968, investor-speculator activities and industrial demand became the determinants of activity in the silver market.

By the turn of the century, silver had lost much of its standing as a precious metal and had become mostly an industrial metal, with about 70% of the metal consumed in industrial applications and photography. Most silver was being recovered as a byproduct of copper, gold, lead, and zinc production. The silver market experienced a period of volatility between 1979 and 1988, with the price reaching a high of $49.45 per ounce in 1980. The price spike, caused by the activities of a few investor-speculators, was short lived. Since then, the price has been mostly stable, averaging around $5.00 per ounce. U.S. mine production of silver in 2000 was about 1,860 tons.

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President's Working Group on Financial Markets, the Congress exempted metals from the close supervision of the Commodities Futures Trading Commission (CFTC). The CFMA, however, did retain for the CFTC the authority to use its considerable tools to protect the public interest against fraud and price manipulation in the exempted metal commodities. Rules to implement the changes in regulating futures are still being finalized by the CFTC (Silver Users Association, 2001).

The Defense Logistics Agency (DLA) delivered all of the remaining 466,600 kilograms (kg) of silver in the National Defense Stockpile to the U.S. Mint for use in its coinage program. Under an agreement with the U.S. Treasury Department, the metal will continue to be carried as DLA stocks until the metal is consumed by the Mint. The transfer marked the end of the silver stockpile era, which at times was a hotly debated issue between silver users and producers. The stockpile is managed by the Defense National Stockpile Center, a branch of the DLA since the late 1960s. Part of the original 5,132 t of silver in the stockpile was auctioned in 1981, and the remainder has been used in the Mint's American Eagle coinage program. With the silver about to be exhausted, the Washington, DC-based Silver Institute turned bullish on the metal. The Institute concluded that when the Mint depletes its silver reserves, it must purchase silver for its coinage program on the open market and thereby boost silver demand by up to 1%. The Silver Users Association (SUA) disagreed, stating that the metal had been merely moved from one government warehouse to another and that the Mint had been using only about 218 metric tons per year (t/yr). At that rate, it would take about 6 years to use up the remaining Mint silver, which the SUA estimated to be about 1,400 t (Platt's Metals Week, 2000b).

The U.S. Mint is responsible for safeguarding much of the Nation's precious metals and strategic stockpiles and is the custodian of a significant portion of its silver resources. The values of the resources are reported at the lower of cost or market value. Amounts and values of custodial silver in the custody of the Mint at the end of September 30, 2000, were 220,063 kg of silver with a market value of $34.58 million (at $4.8875 per fine troy ounce) and a statutory value of $9.148 million. A statutory rate of $1.29292 per fine troy ounce was used to value the custodial reserves held by the Mint (U.S. Mint, August 14, 2001, United States Mint 2000 annual report, accessed August 16, 2001, via URL http://www.usmint.gov).

Production

In 2000, silver was produced in the United States from precious-metal ores at about 30 lode mines and from base-metal ores at about 24 lode mines. More than 30 t of silver was produced at each of 11 mines; their aggregated production equaled about 80% of total domestic production. Fewer than 10 placer operations recovered silver in 2000, and the quantity recovered was less than 1% of the total domestic production of 1,860 t.

The Sunshine Mine and Refinery Complex.—The Sunshine Mine and Refinery Complex, in the Coeur d'Alene mining district near Kellogg, ID, is comprised of the Sunshine Mine, a 1,000-ton-per-day (t/d) concentrator, an antimony refinery, a silver refinery, and associated facilities. The facility is an integrated operation that can produce refined silver with a purity of 99.99%. The silver refinery has the capacity to recover up to 249 t/yr of silver and 1,810 t/yr of copper.

The Sunshine Mine, one of the few remaining primary silver-producing mines, is an underground mine that began operations in 1884 and has produced more than 10,900 t of silver since that time. The underground workings consist of multiple levels developed of the Jewel shaft, the main production shaft. It extends from the surface to a depth of 122 meters (m) and is complemented by other exterior shafts with developed levels as deep as 170 m. The ore extracted from the Sunshine Mine was processed by the flotation concentrator, which produced a high-grade silver concentrate and a lead concentrate. The silver concentrate was transferred to the antimony refinery for antimony removal. After antimony removal, the silver concentrate was either transferred to the company's silver refinery for recovery of silver and copper or sold to a commercial smelter. Sunshine suspended operations at its silver refinery in 1995 pending higher levels of available feed and began shipping its silver concentrate to an outside smelter (Sunshine Mining & Refining Co., 2001a).

In September 2000, Sunshine Mining & Refining filed for chapter 11, allowing the silver miner to reorganize while receiving protection from its creditors (Metal Bulletin, 2000).

On February 16, 2001, Sunshine Mining & Refining announced that the Sunshine Mine was closed. The closing came shortly after Sunshine was notified by its primary customer that it was closing the smelter to which the Sunshine Mine shipped concentrates and that the smelter would no longer accept deliveries. Prior to the announcement, the mine's management sought alternative economic markets for the mine's production; however, the company was not able to secure an alternate and economically viable contract for its concentrates. The mine was placed on care-and-maintenance, and Sunshine was forced to initiate a mass layoff of its employees. The mine produced 121 t of silver in 2000 (Sunshine Mining & Refining Co., 2001b).

McCoy/Cove Gold-Silver Mine.—Ore and waste rock was mined from the open pits at a rate of 51,000 t/d in 2000 compared with 107,000 t/d in 1999. The lower mining rate was attributed to higher development requirements and to mining less productive drift-and-fill cuts as opposed to mining open stopes in 1999. The mill at McCoy/Cove used flotation and agitation leach circuits to recover gold and silver from high-grade oxide ore and sulfide ores not amenable to heap leaching. The majority of the ore processed through the mill in 2000 was from sulfide ores mined during the year. The Cove South Deep underground mine contributed 54,500 t to the mill and produced approximately 333 kg of gold and 134 t of silver. In 2001, McCoy/Cove will process ore from stockpiles and the Cove South Deep underground mine. Residual heap leaching was expected to continue in 2001. As a result, McCoy/Cove is expected to produce about 60% less gold and silver in 2001 compared with the 5,100 kg of gold and 383 t of silver produced in 2000 (Echo Bay Mines Ltd., 2001).

Lucky Friday Mine.—The Lucky Friday Mine, a deep underground silver and lead mine in northern Idaho and 100%

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owned by Hecla Mining Co., has been a producing mine since 1958. In 1991, Hecla discovered several mineralized structures containing high-grade silver ores in an area known as the Gold Hunter property about 1,500 m northwest of the then-existing Lucky Friday workings. A feasibility study was completed in 1997, and full production was reached in the second quarter of 1998. The principal mining method at the Lucky Friday Mine was ramp access, cut-and-fill. Ore produced from the mine was processed in a 1,000 t/d conventional flotation mill. The flotation process produced a silver-lead concentrate and a zinc concentrate. In 2000, ore was processed at a rate of 953 t/d at the mine site and produced 156 t of silver; silver production in 1999 was 138 t. During 2000, about 94.0% of the silver, 93.6% of the lead, and 41.4% of the zinc was recovered (Hecla Mining Co., 2001b).

Greens Creek Mine.—The Greens Creek Mine is a joint-venture arrangement of Hecla Mining Co., Kennecott Greens Creek Mining Co. (manager of the mine), and Kennecott Juneau Mining Co. Kennecott Greens Creek and Kennecott Juneau are wholly owned subsidiaries of Kennecott Corp.

Greens Creek, a polymetallic deposit containing gold, lead, silver, and zinc, lies within the Admiralty Island National Monument in Alaska. The Greens Creek property includes 17 patented load claims and one patented millsite claim in addition to property leases from the U.S. Forest Service. In 2000, Greens Creek mined approximately 1,500 t/d underground from the 200 South, the Southwest, and the West ore zones. Ore from the underground trackless mine was milled at the mine site. The mill produced gold/silver doré and bulk lead and zinc concentrates. In 2000, the mine produced 295 t of silver compared with 327 t in 1999 (Hecla Mining Co., 2001a).

Galena Mine.—On September 9, 1999, Coeur d'Alene Mines Corp. acquired 50% of Silver Valley Resources Corp. from ASARCO Inc., increasing its ownership interest in Silver Valley to 100%. Silver Valley owned and operated the Coeur and Galena Mines in the Coeur d'Alene mining district of Idaho. The Galena Mine property is immediately west of the city of Wallace in Shoshone County in northern Idaho. The mine is an underground silver-copper mine and is served by two vertical shafts. The mine uses the drift-and-fill mining method with sand backfill to extract ore from the high-grade silver-copper vein deposits that constitute the majority of the ore reserves. Silver and copper are recovered by a flotation mill that produces a silver-rich concentrate. Silver recovery through the mill averaged 96% in 2000, which was consistent with 1999. In 2000, the mine produced 125 t of silver compared with 70 t in 1999 (Coeur d'Alene Mines Corp., 2001).

Consumption

Silver has become mostly an industrial metal with demand made up almost exclusively of four major components—electrical and electronic, photography, jewelry, and silverware. In 2000, U.S. consumption of silver, including scrap, was estimated to have been about 5,600 t. Photography, the largest end-use category, accounted for about 2,990 t. The second largest end-use category, batteries/electrical/electronic products, consumed about 1,060 t. About 500 t of silver was consumed in sterlingware, jewelry, and silverplate. Global consumption was estimated to have been 25,000 t, an increase of more than 435 t from that consumed in 1999 (Silver Users Association, 2000).

Prices

Unlike the high prices for platinum-group metals, the price of silver was mostly flat in 2000. Silver prices showed some strength in the first few weeks of the year, reaching the high of $5.75 for the year in early February. Despite strong demand, prices began a long descent in late February that lasted through the rest of the year. The average price in 2000 was $5.00 per ounce, $0.25 below the average for 1999.

Trade

In 2000, the United States imported 3,940 t of silver in ash and residues, ores and concentrates, doré, and refined bullion. The value of these imports was $654 million. Canada (31%), Mexico (38%), and Peru (2%) were the leading foreign sources of imports. The United States exported 380 t of silver in ore and concentrates, refined silver bullion, and doré. The value of these exports was $61.7 million.

World Review

Global silver supply increased in 2000 because of strong growth in the mining sector and disinvestment in a market where the price of silver was in decline for most of the year. Much of the increase in silver supply can be attributed to the return of the Mexican silver industry to a more dominant position after lower than normal output in 1999. Restrictions imposed on Industrias Peñoles S.A. de C.V.'s Torreón processing facility were lifted in February and full production was reached by June 2000. Another factor was increased production at the giant Cannington silver-lead-zinc mine in Australia. Cannington was the leading silver producing mine in 2000, and Peñoles retained its position as the leading silver producer. Global production in 2000 increased 7% to 18,900 t compared with 17,700 t in 1999.

China.—China ended its state monopoly of the buying and selling of silver, first on a trial basis from August 1999, and then officially on January 1, 2000. For the first time since 1949, domestic silver producers are no longer required to sell their production to the People's Bank of China (PBOC), previously the sole purchaser and distributor of silver in China. The Government also discontinued the official silver price, set by the PBOC, and the license system for processing and trading silver articles, excluding silver coinage. The Shanghai-based Huatong Nonferrous Metal Trading Center was designated as the first market to operate silver trade in the country as of January 1, 2000. After opening the market, China encouraged silver exports and limited imports. China produces about 1,300 t/yr of silver and consumes about 800 t/yr (Platt's Metals Week, 2000).

Mexico.—Strong world demand for silver encouraged more investment by Mexican silver producers resulting in a production increase of 6% to 2,620 t in 2000. Output in 1999

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was 2,467 t, substantially lower than the record 2,686 t produced in 1998.

Mexico derives about 50% of its production from primary silver mines and the balance as a byproduct of copper, lead, and zinc production. Mexico's leading silver producer, Peñoles, contributed 1,390 t of mined silver in 2000, more than 50% of the country's total output; refined silver output was a record 2,302 t. Normal operations resumed at the Torreón refinery in 2000, but this was not the only reason for increased production. At Peñoles' Tizapa Mine, output rose by 20% to 212 t, and production at Mina Proaño increased by 84 t to 744 t. The results at Proaño were largely due to expansions completed at the mine in 1999 that raised ore output by about 30% (Silver Institute, 2001, p. 19).

Central America and South America.—In 2000, there was a significant change in the source of silver supply in South America. Output from primary silver mines declined by 42%, while silver as a byproduct from gold and lead-zinc operations increased significantly. The change mostly resulted from the completion of mining at the high-grade Chimberos silver deposit in Chile, which produced 510 t of silver in 1999. With the closure of Chimberos, operators concentrated equipment and personnel on the adjacent La Coipa gold mine, with the result that silver output at the mine increased by more than 50%. Further gains were made at El Peñon gold mine, which contributed 125 t in 2000. According to the Silver Institute, Peru increased its silver output by 9% to 2,438 t, driven by growth in primary gold, copper, and zinc-lead operations. In 2000, Central America's and South America's share of global silver production fell by 2% to 4,500 t, representing about 24% of global production (Silver Institute, 2001, p. 19-20).

Current Research and Technology

Bacteria Resistant to Silver May Have Industrial Applications.—Scientists in Sweden have isolated bacteria that grow silver crystals and store them on the edges of their cell walls. The bacteria, *Pseudomonas stutzeri*, were originally found growing naturally on rocks in silver mines. The researchers were able to grow the bacteria in the laboratory and manipulate the shape in which they formed silver crystals. Most of the crystals were composed of pure silver, but some were silver sulfide. The scientists also discovered that the bacteria could produce and store as much as 25% of the cell's weight in silver. This discovery could lead to new techniques for the recovery of silver from ores, as well as growing superthin and elasticlike silver crystals to specific shapes and sizes for use in electronics and optical applications (Silver News, 2000a).

Government Scientists Produce Silver-Only Dental Fillings.—Metallurgists at the U.S. National Institute of Standards and Technology (NIST) have developed a method for making pure silver powder for use in filling dental cavities. Traditionally, an amalgam of mercury, which has strong corrosion resistance and good mechanical strength, was the material of choice. Now, NIST scientists have found a way to remove naturally occurring silver oxide from the surface of silver metal powder by treating it with a dilute acid solution that removes the oxide layer. The pure silver particles can then be compacted with normal dental tools until they harden. These fillings are 80% as dense and at least as strong as mercury-alloy amalgams. The observed values of flexural strength for the silver compacts were reported to be equal or superior to mercury amalgams. Corrosion resistance, microleakage, and marginal toughness values of the compacts were found to be superior to those of amalgams. Although the American Dental Association has deemed mercury-containing amalgams safe, as long as the materials remain intact, materials that do not contain mercury are more desirable (Advanced Materials & Processes, 2000).

Spent Silver Catalyst May be Used as a Bactericide.—Catalysts make industrial processes, such as the production of plastics, more efficient by increasing the rates of reaction and eliminating unwanted chemical reactions and their byproducts. After periods of use, catalysts become deactivated and must be regenerated. In the case of silver catalysts, refiners remove the silver from its substrate, usually alumina, refine it, and place it onto a new substrate. Although not all of the silver can be economically removed from the substrate, studies have shown that the used silver catalyst substrates retain enough silver to enable the material to be used as an effective bactericide or fungicide. When immersed in water, the spent catalyst will release the more readily available silver immediately, inactivating a large range of bacteria, including *E. coli.* The remaining silver, more strongly bound within the pore structure of the alumina, dissolves more slowly and supplies a concentration of about 5 parts per billion and provides a long-term sanitation effect (Silver News, 2000b).

Outlook

Mine production of silver in 2000, as in the previous 11 years, was less than demand. The difference between demand and newly mined silver was filled by aboveground stocks. In the past 11 years, referred to by some as the "deficit" years, the holders of aboveground stocks have released almost 50,000 t of silver at an average price of $4.86 per ounce, or about $0.14 below the average in 2000. The scale of the deficit was slightly smaller than in 1999 as stockholders' disinvestment of silver (estimated by the Silver Institute at 1,300 t) provided 4.8% of the world's fabrication demand.

The outlook for the silver market depends somewhat on the level of future prices needed to continue filling the gap between demand and newly mined and secondary silver. It has been shown that disinvestment continues at every price level—even when approaching a 20-year low of $3.55 per ounce in 1993. Disinvestment, therefore, is expected to continue to fill the longstanding deficits in the supply of silver. While the market takes these deficits in stride, thanks to the continued release of stocks, lower prices are resulting in some mine closures. If low prices persist or fall even more, it could induce further high-profile mine closures and the suspension or delay of new projects. The size of the currently forecasted deficits could escalate further, which would result in even speedier drawdown of stocks.

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References Cited

Advanced Materials & Processes, 2000, Pure silver powder fills dental cavities effectively: Advanced Materials & Processes, v. 158, no. 3, September, p. 22.

Coeur d'Alene Mines Corp., 2001, 2000 annual report: Coeur d'Alene, ID, Coeur d'Alene Mines Corp., April 2, p. 12-13.

Echo Bay Mines Ltd., 2001, 2000 annual report: Englewood, CO, Echo Bay Mines Ltd., June, 28, p. 13-14.

Hecla Mining Co., 2001a, Greens Creek Mine, *in* 2000 annual report: Coeur d'Alene, ID, Hecla Mining Co., April, 12, p. 10-11.

———2001b, Lucky Friday Mine, *in* 2000 annual report: Coeur d'Alene, ID, Hecla Mining Co., April 12, p. 6-8.

Metal Bulletin, 2000, Sunshine Mining & Refining files for chapter 11: Metal Bulletin, no. 8585, September 4, p. 7.

Platt's Metals Week, 2000a, China opens silver market: Platt's Metals Week, v. 71, no. 8, February 21, p. 4.

———2000b, DLA to ship last silver to US Mint: Platt's Metals Week, v. 71, no. 49, December 4, p. 5.

Silver Institute, 2001, World silver survey 2001: Washington, DC, Silver Institute, May, 84 p.

Silver News, 2000a, Bacteria resistant to silver may have industrial applications: Silver News, April-May, p. 4.

———2000b, Novel silver bactericide provides new sanitation convenience: Silver News, August-September, p. 3.

Silver Users Association, 2001, U.S. silver summary—2000: Washington, DC, Silver Users Association, May 23, p. 2.

Sunshine Mining & Refining Co., 2001a, 2000 annual report: Dallas, Sunshine Mining & Refining Co., March 16, p. 4-6.

———2001b, Sunshine Mining announces closing of Sunshine Mine: Dallas, Sunshine Mining Co. news release, February 16, 1 p.

U.S. Geological Survey, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Precious Metals. Mineral Industry Surveys, monthly.
Silver. Ch. in Mineral Commodity Summaries, annual.
Silver. Ch. in Minerals Yearbook, annual.
Silver. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Silver. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT SILVER STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Mine production	metric tons	1,570	2,180	2,060	1,950	1,860
Value	thousands	$262,000	$329,000	$368,000	$329,000	NA
Refinery production:						
Domestic and foreign ores and concentrates	metric tons	NA	2,200	2,300	2,000	2,780
Scrap (old and new)	do.	NA	1,360	1,700	1,500	1,680
Exports, refined	do.	2,900	2,980	2,250	481	279
Imports for consumption, refined	do.	2,580	2,120	2,800	2,660	3,810
Stocks, December 31:						
Industry	do.	NA	395	400	NA	462
Futures exchanges	do.	4,550	3,430	2,360	2,490 r/	2,920
Department of the Treasury	do.	402	484	582	617	220
National Defense Stockpile	do.	1,450	1,220	1,030	778	458
Price, average per troy ounce 2/		$5.19	$4.89	$5.54	$5.25	$5.00
Employment, mine and mill workers 3/		1,400	1,550	1,550	1,500	1,200
World, mine production	metric tons	15,100 r/	16,500 r/	17,200 r/	17,600 r/	18,300 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Price data are the annual Handy & Harman quotations published in Platt's Metals Week.

3/ Employment data are from the Mine Safety and Health Administration.

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TABLE 2
MINE PRODUCTION OF SILVER IN THE UNITED STATES, BY STATE 1/

(Kilograms)

State	1998	1999	2000
Arizona	211,000	183,000	132,000
California	11,300	7,670	8,610
Colorado	W	W	W
Idaho	447,000	416,000	416,000
Nevada	670,000	597,000	633,000
South Dakota	1,960	W	1,410
Washington	622	W	1,560
Other 2/	723,000	748,000	671,000
Total	2,060,000	1,950,000	1,860,000

W Withheld to avoid disclosing company proprietary data, included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Alaska, Missouri, Montana, New Mexico, Utah, and States indicated by symbol W.

TABLE 3
LEADING SILVER-PRODUCING MINES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT 1/

Rank	Mine	County and State	Operator	Source of silver
1	McCoy/Cove	Lander, NV	Echo Bay Mines Limited	Gold ore.
2	Greens Creek	Juneau, AK	Kennecott Greens Creek Mining Company	Zinc ore.
3	Rochester	Pershing, NV	Coeur Rochester, Inc.	Gold ore.
4	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Lead-zinc ore.
5	Sunshine	Shoshone, ID	Sunshine Mining & Refining Co.	Silver ore.
6	Lucky Friday	do.	Hecla Mining Company	Do.
7	Bingham Canyon	Salt Lake, UT	Kennecott Utah Copper Corp.	Copper-molybdenum ore.
8	Galena	Shoshone, ID	Silver Valley Resources Corp.	Silver ore.
9	Ken Snyder	Elko, NV	Euro-Nevada	Gold ore.
10	Mission Complex 2/	Pima, AZ	ASARCO Incorporated	Copper ore.
11	Montana Tunnels	Jefferson, MT	Apollo Gold Co.	Zinc ore.
12	Bagdad	Yavapai, AZ	Phelps Dodge Corp.	Copper-molybdenum ore.
13	Denton-Rawhide	Mineral, NV	Kennecott Minerals Company	Gold ore.
14	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper-molybdenum ore.
15	Sierrita	Pima, AZ	do.	Do.
16	Continental	Silver Bow, MT	Montana Resources Inc.	Do.
17	Brushy Creek	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
18	Round Mountain	Nye, NV	Round Mountain Gold Corp.	Gold ore.
19	Buick	Iron, MO	Doe Run Resources Corp.	Lead ore.
20	Betze-Post/Goldstrike	Eureka, NV	Barrick Gold Corp.	Gold ore.
21	Ray	Pinal, AZ	ASARCO Incorporated	Copper ore.
22	Carlin Mines Complex	Elko, Eureka, NV	Newmont Gold Company	Gold ore.
23	Chino	Grant, NM	Phelps Dodge Corp.	Copper-molybdenum ore.
24	Lone Tree	Humboldt, NV	Newmont Gold Corp.	Gold ore.
25	Fletcher	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
26	McLaughlin	Napa, CA	Homestake Mining Company	Gold ore.
27	Sweetwater	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
28	Beartrack	Lemhi, ID	Meridian Gold Inc.	Gold ore.
29	Dee Gold	Elko, NV	Glamis Gold Ltd. Dee Gold Mining Company	Do.
30	Rosebud	Pershing, NV	Hecla Mining Company	Do.
31	Cresson	Teller, CO	Cripple Creek & Victor Gold Mining Co.	Do.
(3/)	Florida Canyon	Pershing, NV	Florida Canyon Mining, Inc.	Do.

1/ The mines on this list accounted for 97% of U.S. mine production in 2000.
2/ Includes Eisenhower, Mission, Pima, and San Xavier Mines.
3/ Production data at Florida Canyon are withheld; mine is among the top 32 silver-producing mines in the United States, but is not shown in rank order to avoid disclosing company propriety data.

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TABLE 4
U.S. EXPORTS OF SILVER, BY COUNTRY 1/

Year and country	Silver ores and concentrates		Bullion		Doré		Total	
	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)
1999	70,800	$14,200	481,000	$84,400	64,400	$11,400	616,000	$110,000
2000:								
Argentina	--	--	--	--	--	--	--	--
Armenia	--	--	--	--	--	--	--	--
Australia	--	--	398	78	--	--	398	78
Austria	--	--	--	--	--	--	--	--
Bahamas, The	--	--	--	--	--	--	--	--
Belgium	--	--	--	--	--	--	--	--
Brazil	90	16	--	--	--	--	90	16
Canada	57,100	7,720	2,170	421	--	--	59,300	8,140
China	--	--	--	--	--	--	--	--
Colombia	--	--	152	19	--	--	152	19
Denmark	--	--	--	--	--	--	--	--
Dominican Republic	--	--	--	--	--	--	--	--
Ecuador	--	--	--	--	--	--	--	--
Egypt	--	--	--	--	--	--	--	--
Finland	--	--	--	--	--	--	--	--
France	13	3	666	86	--	--	679	89
Germany	39	7	31	6	--	--	70	13
Greece	--	--	--	--	--	--	--	--
Guatemala	--	--	97	18	--	--	97	18
Hong Kong	--	--	--	--	--	--	--	--
India	--	--	19,100	3,000	--	--	19,100	3,000
Ireland	--	--	--	--	--	--	--	--
Israel	--	--	--	--	--	--	--	--
Italy	--	--	--	--	--	--	--	--
Japan	240	44	108,000	18,300	--	--	109,000	18,400
Korea, Republic of	--	--	--	--	--	--	--	--
Lebanon	--	--	--	--	--	--	--	--
Mexico	7,650	1,320	33,900	5,620	18,400	3,530	60,000	10,500
Netherlands	--	--	24	4	--	--	24	4
Netherlands Antilles	--	--	--	--	--	--	--	--
New Zealand	--	--	--	--	--	--	--	--
Panama	--	--	--	--	--	--	--	--
Peru	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	--	--	--	--
Poland	--	--	--	--	--	--	--	--
Romania	--	--	--	--	--	--	--	--
Russia	--	--	--	--	--	--	--	--
Singapore	--	--	--	--	27	6	27	6
South Africa	--	--	--	--	--	--	--	--
Spain	--	--	--	--	--	--	--	--
Sweden	--	--	--	--	--	--	--	--
Switzerland	--	--	10,100	1,560	12,500	2,060	22,600	3,610
Taiwan	--	--	1,840	316	239	59	2,080	375
Thailand	--	--	312	46	--	--	312	46
Trinidad and Tobago	--	--	--	--	--	--	--	--
United Kingdom	--	--	98,000	16,000	4,800	787	103,000	16,800
Uruguay	--	--	3,390	620	--	--	3,390	620
Vietnam	--	--	--	--	--	--	--	--
Other	--	--	37	8	--	--	37	8
Total	65,100	9,110	279,000	46,100	36,000	6,440	380,000	61,700

See footnotes at end of table.

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TABLE 4--Continued
U.S. EXPORTS OF SILVER, BY COUNTRY 1/

Year and country	Other unwrought silver		Metal powder		Silver nitrate		Semimanufactured forms 2/		Waste and scrap	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
1999	75,100	$14,400	324,000	$55,100	62,500	$7,330	122,000	$28,700	1,310,000	$223,000
2000:										
Argentina	--	--	--	--	--	--	495	97	--	--
Armenia	--	--	--	--	--	--	--	--	5,740	746
Australia	244	54	--	--	4,290	447	33	16	--	--
Austria	--	0	399	92	--	--	5	23	--	--
Bahamas, The	21	5	--	--	100	19	--	--	--	--
Belgium	231	55	80	20	--	--	5,150	1,130	255,000	73,400
Brazil	497	80	--	--	575	73	2,460	334	617	80
Canada	3,720	681	21,800	3,480	149,000	22,300	64,400	10,400	521,000	75,800
China	--	--	14,000	2,660	34,200	3,670	1,880	429	259,000	34,200
Colombia	30	6	49	3	--	--	39	8	--	--
Denmark	--	--	--	--	--	--	225	62	--	--
Dominican Republic	4,830	1,060	--	--	53	10	12	4	--	--
Ecuador	--	--	--	--	--	--	--	--	1,090	141
Egypt	--	--	--	--	--	--	1,450	346	--	--
Finland	--	--	224	35	--	--	18	16	--	--
France	277	97	17,900	3,130	--	--	4,030	1,620	731	108
Germany	11,400	2,340	65,000	11,700	63	22	2,100	931	161,000	45,200
Greece	--	--	317	48	--	--	--	--	--	--
Guatemala	--	--	--	--	--	--	--	--	--	--
Hong Kong	563	123	17,600	3,180	--	--	3,860	900	7,390	998
India	302	69	197	55	--	--	103	34	702	78
Ireland	--	--	2,880	432	--	--	248	59	21,700	3,380
Israel	--	--	411	244	--	--	264	83	500	246
Italy	72	41	318	53	--	--	3,700	661	101,000	12,800
Japan	386	108	142,000	28,000	43	8	7,970	1,810	53,500	16,500
Korea, Republic of	2,230	613	22,100	4,780	--	--	852	431	12,000	2,130
Lebanon	58	10	470	79	--	--	--	--	--	--
Mexico	4,450	755	4,630	812	27,300	2,690	19,500	4,140	53,700	10,900
Netherlands	92	21	10,300	1,770	38	3	790	164	505	68
Netherlands Antilles	227	50	--	--	--	--	--	--	--	--
New Zealand	--	--	--	--	--	--	709	236	--	--
Panama	--	--	--	--	--	--	113	22	--	--
Peru	--	--	26	4	--	--	175	17	--	--
Philippines	13	22	--	--	42	3	73	69	123	16
Poland	--	--	--	--	--	--	--	--	7,940	1,030
Romania	143	35	--	--	--	--	1	3	--	--
Russia	--	--	--	--	217	5	--	--	--	--
Singapore	311	69	1,640	370	102	3	2,790	756	503	65
South Africa	413	99	--	--	--	--	--	--	9,710	3,010
Spain	--	--	22	7	--	--	11,600	3,060	--	--
Sweden	38	9	10,600	1,450	--	--	2	4	44,600	6,650
Switzerland	112	131	580	89	--	--	220	259	8,340	2,680
Taiwan	22,200	4,030	57,500	18,600	478	66	7,970	2,120	4,940	649
Thailand	2,300	444	632	103	14	3	487	90	--	--
Trinidad and Tobago	--	--	--	--	44	3	104	20	--	--
United Kingdom	2,080	465	32,800	8,500	203	46	4,080	4,740	133,000	86,400
Uruguay	131	29	--	--	--	--	--	--	--	--
Vietnam	--	--	--	--	--	--	--	--	452	59
Other	125	28	79	20	53	10	260	99	53	63
Total	57,500	11,500	424,000	89,700	217,000	29,400	148,000	35,200	1,670,000	377,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Containing 99.5% or more by weight of silver.

Source: U.S. Census Bureau.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY 1/

Year and country	Silver ores and concentrates		Base metal ores and concentrates		Ash and residues		Bullion		Doré		Total	
	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)
1999	10,800	$1,970	2,750	$440	101,000	$8,970	2,660,000	$453,000	407,000 r/	$81,600	3,180,000	$546,000
2000:												
Argentina	--	--	--	--	--	--	--	--	--	--	--	--
Australia	--	--	--	--	1,310	213	--	--	--	--	1,310	213
Belgium	--	--	--	--	--	--	859	129	--	--	859	129
Brazil	--	--	--	--	--	--	--	--	--	--	--	--
Canada	1,420	229	--	--	23,900	2,810	1,210,000	202,000	--	--	1,240,000	205,000
Chile	--	--	--	--	--	--	7,000	1,060	49,600	13,600	56,600	14,600
China	--	--	--	--	--	--	606	106	--	--	606	106
Colombia	--	--	--	--	--	--	876	121	1,570	225	2,450	346
Costa Rica	--	--	--	--	--	--	--	--	--	--	--	--
Dominican Republic	--	--	--	--	--	--	--	--	--	--	--	--
El Salvador	--	--	--	--	--	--	--	--	--	--	--	--
France	--	--	--	--	--	--	100	14	--	--	100	14
Germany	--	--	--	--	--	--	--	--	--	--	--	--
Hong Kong	--	--	--	--	--	--	--	--	--	--	--	--
India	--	--	--	--	--	--	--	--	--	--	--	--
Japan	--	--	--	--	(3/)	239	--	--	--	--	(3/)	239
Korea, Republic of	--	--	--	--	--	--	--	--	--	--	--	--
Malaysia	--	--	--	--	--	--	--	--	--	--	--	--
Mexico	--	--	--	--	9,980	871	1,390,000	223,000	22,800	3,860	1,420,000	227,000
Netherlands	--	--	--	--	--	--	--	--	--	--	--	--
New Zealand	--	--	--	--	--	--	--	--	--	--	--	--
Nicaragua	--	--	--	--	--	--	140	26	--	--	140	26
Panama	--	--	--	--	--	--	456	56	--	--	456	56
Peru	--	--	--	--	--	--	86,700	13,900	--	--	86,700	13,900
Philippines	--	--	--	--	--	--	--	--	--	--	--	--
Poland	--	--	--	--	--	--	--	--	--	--	--	--
Russia	--	--	--	--	--	--	54,100	8,420	--	--	54,100	8,420
Singapore	--	--	--	--	--	--	--	--	--	--	--	--
Spain	--	--	--	--	--	--	--	--	--	--	--	--
Sweden	--	--	--	--	--	--	--	--	--	--	--	--
Switzerland	--	--	--	--	--	--	386	60	--	--	386	60
Taiwan	--	--	--	--	--	--	--	--	--	--	--	--
United Arab Emirates	--	--	--	--	--	--	--	--	--	--	--	--
United Kingdom	--	--	--	--	20,600	3,210	1,060,000	180,000	--	--	1,080,000	183,000
Other	--	--	--	--	--	--	334	69	--	--	334	69
Total	1,420	229	--	--	55,800	7,340	3,810,000	629,000	73,900	17,600	3,940,000	654,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY 1/

Year and country	Other unwrought silver (gross weight)		Metal powder (gross weight)		Silver nitrate (gross weight)		Semimanufactured forms 2/ (gross weight)		Waste and scrap (gross weight)	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
1999	126,000	$22,200	120,000	$26,400	4,480 r/	$364	137,000 r/	$23,900 r/	1,640,000	$123,000 r/
2000:										
Argentina	--	--	--	--	--	--	--	--	16,000	115
Australia	--	--	41	12	30	3	--	--	39	455
Belgium	--	--	--	--	18,500	1,120	--	--	16,900	1,340
Brazil	--	--	4,970	524	2,520	258	7,700	705	375	491
Canada	136,000	24,800	71,000	12,200	421	77	81,800	17,100	420,000	56,600
Chile	633	800	--	--	--	--	15	7	236	63
China	(3/)	4	--	--	--	--	63	9	9,040	1,570
Colombia	--	--	--	--	--	--	--	--	--	--
Costa Rica	--	--	--	--	--	--	--	--	5,540	135
Dominican Republic	--	--	113	15	--	--	--	--	5,180	1,800
El Salvador	--	--	--	--	--	--	--	--	111	24
France	--	--	750	113	1,150	124	4,730	1,020	62,400	1,380
Germany	5	10	14,400	2,960	--	--	26,900	3,610	147,000	14,400
Hong Kong	--	--	--	--	--	--	11	5	40,300	196
India	--	--	--	--	--	--	405	79	--	--
Japan	39	16	117,000	26,400	251	42	1,230	550	16,800	11,500
Korea, Republic of	--	--	10	2	--	--	4,170	437	66,300	3,280
Malaysia	--	--	--	--	--	--	--	--	75,000	4,290
Mexico	66,800	11,000	18,700	3,120	799	92	4,760	334	65,400	10,100
Netherlands	--	--	32	3	--	--	240	73	668	272
New Zealand	--	--	--	--	--	--	--	--	198	406
Nicaragua	--	--	--	--	--	--	--	--	--	--
Panama	--	--	--	--	--	--	--	--	236	13
Peru	353	447	6,770	1,040	--	--	--	--	406	61
Philippines	--	--	--	--	--	--	--	--	28,200	806
Poland	9	11	--	--	--	--	1,500	125	--	--
Russia	--	--	--	--	--	--	72	13	--	--
Singapore	--	--	--	--	--	--	--	--	2,400	636
Spain	--	--	--	--	--	--	371	48	2,370	599
Sweden	--	--	--	--	--	--	--	--	97	1,440
Switzerland	--	--	343	72	--	--	359	124	689	112
Taiwan	14	12	65	11	--	--	355	55	39,300	300
United Arab Emirates	--	--	--	--	--	--	--	--	87,300	670
United Kingdom	46	15	37	9	500	58	4,250	1,190	3,560	3,970
Other	67	29	48	10	--	--	829	376	17,300	17,100
Total	204,000	37,200	235,000	46,500	24,200	1,770	140,000	25,800	1,130,000	134,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Containing 99.5% or more by weight of silver.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 6
SILVER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria e/	2	2	2	1 r/	1
Argentina	50	53	36	74 r/	78
Australia	1,013	1,106	1,474	1,720	2,060 3/
Bolivia	384	387	404	422	434 3/
Brazil 4/	30	27	34	42 r/	41
Bulgaria	49	32	24	25 e/	25
Burma	4	2	3	4	3
Canada	1,309	1,224 r/	1,196 r/	1,174 r/	1,161 3/
Chile	1,047	1,091	1,340	1,380 r/ e/	1,242 3/
China e/	1,140	1,300	1,300 r/	1,320 r/	1,600
Colombia 5/	6	4	5	7 r/ e/	8
Congo (Kinshasa) e/	1	1	1	1	1
Costa Rica e/	(6/)	(6/)	(6/) 3/	(6/) e/	(6/)
Dominican Republic	17	12	7	3 r/	--
Ecuador	1	2	2 e/	2 e/	2
El Salvador	--	(6/)	(6/)	(6/) e/	(6/)
Fiji	2	3	2	2 r/	1 3/
Finland e/	33 r/	32 e/	30	32 r/	24
France	2 e/	2	2 r/	1 r/	1
Ghana e/	2	3	4	4	36
Greece	17	45	45 e/	46 r/	37 3/
Honduras	29	35 e/	43	47	46
India	36	50	52	54 e/	40
Indonesia	255	219	349 3/	288 r/	26 3/
Iran e/	60	60	19 r/	21 r/	20
Ireland	15	13	13 e/	12 e/	16
Italy 7/	9	10 e/	10 e/	10 e/	4
Japan	85	87	94	94	104
Kazakhstan e/	468 3/	690 r/	726 r/	904 r/	927
Korea, North e/	50	50	50	50	50
Korea, Republic of 5/	254	268	339	489	591 3/
Macedonia e/	20 r/	19 r/	20 r/	22 r/	20
Malaysia	10	10	7	4 r/	(6/) p/
Mali e/	(6/)	1	1	1	1
Mexico	2,528	2,679	2,686	2,467 r/	2,621 3/
Mongolia e/	19	23	20	20	25
Morocco	200	261	307 r/	278 r/	289
Namibia	42	41	23	18 e/	18
New Zealand	30	32	23 r/ 3/	24 r/	23
Nicaragua	2 e/	3	4	3	3
Oman	--	--	1	1	1
Panama	1	2	2 e/	2	2
Papua New Guinea	59 r/	49 r/	59 r/	67 r/	73
Peru	1,970	2,090 r/	2,025 r/	2,231 r/	2,438 3/
Philippines	25	20	18 r/	18 r/	17
Poland	935	1,038 r/	1,108 r/	1,100	1,100
Portugal	34 r/	34 r/	32 r/	27 r/	25
Romania e/	60	60	60	50 r/	50
Russia e/	400	400	350	375	370
Saudi Arabia	17	17	14 r/	10 r/	9
Serbia and Montenegro	69	43	34 r/	8 r/	8 3/
Solomon Islands e/	(6/)	(6/)	2 r/ 3/	2 r/ 3/	(6/)
South Africa	169	144	144	141	144
Spain	109 r/	66 e/	47 r/	96 r/ e/	70
Sweden	272	304	299	300	300
Tajikistan	NA	NA	5	5	5
Tunisia	3	1 e/	3 r/	4 r/	4
Turkey e/	70	90	110	110	110
United States	1,570	2,180	2,060	1,950	1,860 3/
Uzbekistan e/	70	70	70	75	75
Zambia 8/	9	7	8	5 r/	5
Zimbabwe	10	6	7	5 r/	4 3/
Total	15,100 r/	16,500 r/	17,200 r/	17,600 r/	18,300

See footnotes at end of table.

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TABLE 6--Continued
SILVER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through August 11, 2001.
3/ Reported figure.
4/ Includes the following quantities, in kilograms, identified as secondary silver: 1996--38,000; 1997--32,000; 1998--40,000; 1999--40,000 (estimated); and 2000--40,000 (estimated).
5/ Smelter and/or refinery production.
6/ Less than 1/2 unit.
7/ Includes production from imported ores.
8/ Year beginning April 1 of that stated.

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SLAG—IRON AND STEEL

By Rustu S. Kalyoncu

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant.

As early as 350 B.C., the Greek philosopher-physician Aristotle prescribed iron slags for healing wounds. In the ensuing centuries, a number of applications for iron and steel slags were found. However, it was not until the early 20th century, when the modern processes of iron and steel production were developed, that the commercial, large-scale use of iron and steel slags became economical.

The American Society of Testing and Materials (ASTM) (1999) defines blast furnace slag as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace." To the casual observer, one of the most striking features of an iron and steel plant is the site of a mountainous slag pile that presents a continuous display as ladle after ladle pours its incandescent load down the side in the endless accumulation of this waste product. Almost a century ago, the term waste product aptly described slag. Slag was considered to be essential in the production of iron, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The usefulness of slags was realized with the first ore smelting process. The use of slags became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial byproducts was strong and storage space for byproducts was lacking. Shortly after, many markets for slags opened in Europe, the United States, and elsewhere in the world.

In the production of iron, the blast furnace (BF) is charged with iron ore, fluxing agents (usually limestone and dolomite) and coke as fuel and the reducing agent. The iron ore is a mixture of iron oxides, silica, and alumina. From this and the added fluxing agents, alkaline earth carbonates, molten slag, and iron are formed. Oxygen in the preheated air blown into the furnace combines with the carbon of the coke to produce the needed heat and carbon monoxide. At the same time, the iron ore is reduced to iron, mainly through the reaction of the carbon monoxide with the iron oxide to yield carbon dioxide (CO_2) and metallic iron. The fluxing agents dissociate into calcium and magnesium oxides and carbon dioxide. The oxides of calcium and magnesium combine with silica and alumina to form slag. The slag is transported into a cooling pit either directly or via iron ladles, depending on the distance between the pit and the furnace.

The principal constituents of iron and steel slags are silica (SiO_2), alumina (Al_2O_3), calcia (CaO), and magnesia (MgO), which make up 95% of the composition. Minor elements include manganese, iron, and sulfur compounds, as well as trace amounts of several others. The physical characteristics, such as density, porosity, and particle size, are affected by the cooling rates of the slag and its chemical composition. Depending on the cooling method, three types of BF slag are produced: air-cooled, expanded, and granulated.

Allowing the molten slag to cool slowly in air in an open pit produces air-cooled slag. Air-cooled blast furnace slag is defined in ASTM standard C-125 (American Society for Testing and Materials, 1999) as "the material resulting from solidification of molten blast furnace slag under atmospheric conditions. Subsequent cooling may be accelerated by application of water to the solidified surface." The solidified slag has a vesicular structure with closed pores. The rough vesicular texture of slag gives it a greater surface area than smoother aggregates of equal volume and provides an excellent bond with portland cement, as well as high stability in asphalt

Slag—Iron and Steel in the 20th Century

Early use of blast furnace slag in the United States was prompted by the desire to make use of material that was considered an expensive waste product. Its use in earnest started in the early 1900s in the construction field, principally for railroad ballast, portland-cement-concrete aggregate, and aggregates for bituminous and other types of road construction. The National Slag Association carried out a survey of slag shipments in the United States for the first time in 1938. In 1939, the first year for which comprehensive figures of marketed slag are available, 8.3 million metric tons of blast furnace slag valued at $6.4 million was used. The slag output from blast furnaces in 1947, the first year in which the U.S. Bureau of Mines collected production statistics, reached almost 30 million tons. Most slag was used in highway construction and railroad ballast.

In 2000, 8.9 million tons of blast furnace slag valued at $58.3 million and 5.1 million tons of steel slag valued at $20.1 million were used. Major uses were in road construction, asphaltic concrete aggregate, portland cement manufacture, and various concrete products. In the early years of slag use, prospective consumers thought that slag was subject to disintegration and corrosion and was brittle. Slag cements also were questioned, and slag wool was believed to have high sulfur content. Only after years of research and promotion were these objections overcome. In 2000, the ferrous slag industry enjoyed the benefits of many individual and collective efforts expended in the development of slag markets. A broader market existed for slag, from mineral wool to roofing granules to agriculture. Virtually all of the slag produced by the iron and steel industry throughout the world was used in such applications as asphaltic concrete aggregate, cement extenders, fill, railroad ballast, road bases, and roofing granules.

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mixtures.

Expanded slag is formed through controlled rapid cooling of molten slag in water or in water with combination of steam and compressed air. Steam and other gases enhance the porosity and vesicular nature of the slag, resulting in a lightweight aggregate suitable for use in concrete. Quenching the molten slag into glass granules by using high-pressure water jets produces granulated slag. Quenching prevents the crystallization of minerals constituting the slag composition, thus resulting in a granular, glassy aggregate. This slag is crushed, pulverized, and screened for use in various applications, particularly in cement production, because of its pozzolanic (hydraulic cementitious) characteristics.

Slags are also coproducts of steelmaking processes. Production of steel calls for the removal of excess silicon by mineralization and of carbon by oxidation from pig or crude iron. Steel slag is a hard, dense material somewhat similar to air-cooled iron slag. It contains significant amounts of free iron, giving it its high density and hardness, which make it particularly suitable as a road construction aggregate.

Slag is transported to processing plants, where it undergoes crushing, grinding, and screening operations to meet various use specifications. Processed slag is either shipped to its buyer for immediate use or, in slack seasons, stored.

Legislation and Government Programs

Classification of slags under several standard waste categories has been the subject of a number of past Government initiatives. The National Slag Association reported no major Government action concerning slag in 2000 (R.Y. Twitmyer, President, National Slag Association, oral commun., 2000). The effect of increased spending on highway construction and repairs, as a result of the passage of the Transportation Equity Act for the 21st century (Public Law 105-178) by Congress in 1998, with its $205 billion spending plan, did not show on the consumption and price of slags in 2000.

The Portland Cement Association is promoting slag use in portland cement production. The potential for a carbon tax levy on CO_2 emissions may provide the cement producers with incentives to find ways of reducing CO_2 emissions in portland cement production, where the burning fuel and decomposition of carbonates in the raw feed contribute to CO_2 emissions.

Texas Industries has developed a process for cement clinker production involving the use of steel slag. In this process, called CemStar, steel slag is fed into the rotary kiln as a part of the raw meal. Replacing a part of the raw meal directly with slag will result in the lowering of CO_2 emissions directly proportional to the quantities of slag used. Additional refinements of the process have been reported (Robert D. Rogers, President, Texas Industries, oral commun., 2000).

Production

The iron and steel industry does not routinely measure slag output; therefore, actual annual ferrous slag production data in the United States do not exist. The data collected by the U.S. Geological Survey (USGS) reflect the slag processing industry's sales rather than the output. Slag outputs in iron and steel production are highly variable and depend, partly, on the composition of the raw materials and the type of furnace. Typically, for ore feed with 60% to 65% iron, blast furnace slag production ranges from about 220 to 370 kilograms per metric ton of pig iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as 1 ton of slag per ton of pig iron. Steel slag outputs are approximately 20% by mass of the steel output. About one-half of the slag is entrained steel, which is generally recovered and returned to the furnace. After removal of the entrained steel, the marketable slag is equivalent to about 10% to 15% of the original steel output.

According to statistics reported by the American Iron and Steel Institute, U.S. pig iron production was about 46 million tons (Mt) and 48 Mt in 1999 and 2000, respectively. The iron slag production figures for these years were about 11.5 Mt and 12 Mt in 1999 and 2000, respectively. Similarly, U.S. steel production was reported to be 97 Mt for 1999 and 101 Mt for 2000. The expected steel slag production was about 11 Mt for 1999 and 13 Mt in 2000. As with the United States, no data are available on world slag production. The International Iron and Steel Institute (2000, p. MM16) reported the world pig iron output to be about 570 Mt and crude steel production to be 828 Mt in 2000. The estimated figures for ferrous slag production from this output was approximately 200 Mt.

Tables 1 through 8 list data compiled from the USGS survey of domestic slag processors. The data for 1999 and 2000 reflect a response by 90% of the processors queried. Where applicable, estimates have been incorporated for data omitted from the returned questionnaires. Table 8 lists the production facilities that responded to the survey in 2000. Redland Mill Services no longer appears in the table because Lafarge Corp. bought it 2 years ago.

Nucor Corporation's new 1-million-ton-per-year electric-arc furnace steel mill in Hertford County, NC, the construction of which was started in 1998 (Kalyoncu, 1999), became operational in October 2000 (Giff Daughtridge, plant manager, Nucor Plant, oral commun., 2001). Currently [2000], the mill is operating at 70% capacity and generating approximately 25,000 tons of slag, which is processed by Heckett MultiServ Co.

GSC Partners is in the process of acquiring Envirosource (R.Y. Twitmyer, National Slag Association, oral commun., 2001).

Consumption

Uses of iron and steel slags range from building and road construction to waste stabilization. Iron and steel slags are also used in cement manufacture, concrete aggregates, agricultural fill, glass manufacture, and as a mineral supplement and liming agent in soil amendment. The correlation between slag production and availability is not a good indicator of consumption trends because time lags between production and sale of the slag to the final customer can be significant. The primary reason for the lag is the necessity of aging the new slag to reduce its free-lime content for certain applications, such as concrete production. High levels of free lime can adversely affect concrete performance. Generally, slag, especially steel slag, will be stored to cure for 6 months or longer to allow expansion of dicalcium silicate and to reduce the free-lime content to acceptable levels. Furthermore, many slag producers accumulate large stockpiles to be able to participate in bids to supply large construction projects.

Air-cooled slag accounted for the bulk of slag production (sales) in the United States. The total U.S. sales of about 9 Mt, worth more than $59 million, of domestically produced air-cooled blast furnace slag recorded a slight increase in value (table 1). Expanded and granulated slag sales increased. Total revenues of more than $141 million (iron plus steel slags) for

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2000 were slightly higher than those of 1999. The mid-Atlantic region, for a second year, remained the leader in sales value of blast furnace slag with $55 million, accounting for more than 45% of total revenues for the whole country, with the north-central region accounting for most of the remaining business (table 3).

In 2000, sales for concrete and asphaltic road construction, including road base, again accounted for more than three quarters of the consumption of air-cooled BF slags in the United States; other uses were in soil conditioning, sewage treatment, and mineral wool production (table 4).

Road base was the primary use of steel slag, followed by fill and asphaltic concrete aggregates. The steel slag sales of $20.1 million in 2000 lagged behind the 1999 figure of $23 million by almost 13% (table 5). Slag prices showed a range of values depending on their use categories (table 6). A significant amount of slag, 2.4 Mt, was never shipped but used at the plants (table 7).

In 2000, the United States imported 1.5 Mt of ferrous slags. Granulated blast furnace slag (GGBFS), which commands the highest price among ferrous slags, led the imports. In 2000, approximately 1 Mt of GGBFS was imported. Imports of GGBFS, in descending order, were mainly from Italy, Canada, France, South Africa, and Brazil. Principal discharge ports were Tampa, FL, New Orleans, LA, Philadelphia, PA, and Detroit, MI. In 2000, imports accounted for about 5% of total ferrous slag shipments in the United States.

Transportation

Most of the of ferrous slag sold and not consumed at the plant was transported by truck; rail and barge transportation accounted for 21.5% of the total (table 7). Most ferrous slag was transported less than 100 kilometers; trucks were the most economical means of transportation for such distances.

Current Research and Technology

No significant developments were made in slag processing technology during 2000. Because slag is a low unit-value, high-volume commodity, and slag processing is an established, conservative industry, all the slag that is processed is readily sold. Therefore, the industry seldom feels the need for innovations and, therefore, invests little, if any, in expensive research efforts. Previously reported advancements in granulating techniques (Kalyoncu, 1999) resulted in some improvements in slag granulation systems, especially in reducing the energy costs.

Outlook

Potential classification by the U.S. Environmental Protection Agency of iron and steel slags as hazardous wastes is of constant concern to the slag industry. Absent such a classification, ferrous slag has a secure future in the construction industry. Some blast furnace operations, however, have been closing because of an inability to compete in the marketplace. In the case of continuing plant closings, availability of domestic blast furnace slag may decline, which may necessitate an increase in imports. With its more limited uses, the long-term supply of steel slag appears to be more stable. An increase in the use of steel slags may be on the horizon as blast furnace slag production declines.

References Cited

American Society for Testing and Materials, 1999, Standard terminology relating to concrete and concrete materials: West Conshohocken, PA, American Society for Testing and Materials, 4 p.

International Iron and Steel Institute, 2000, Steel statistical yearbook: Brussels, International Iron and Steel Institute, 112 p.

Kalyoncu, R.S., 1999, Slag—Iron and steel: U.S. Geological Survey Mineral Commodity Summaries 1999, p. 94-95.

U.S. Geological Survey Publications

Iron and Steel. Ch. in Mineral Commodity Summaries, annual.

Slag—Iron and Steel. Ch. in Mineral Commodity Summaries, annual.

TABLE 1
IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES 1/ 2/

(Million metric tons and million dollars)

	Blast furnace slag									
	Air-cooled		Expanded 3/		Total		Steel slag		Total slag	
Year	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value
1999	8.9	58.30	1.9	62.20	10.8 r/	120.00	6.2 r/	23.00 r/	17.1 r/	140.40 r/
2000	8.9	58.60	2.3	62.40	11.2	121.00	5.1	20.10	16.3	141.20

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Excludes imported slag.

3/ Includes granulated slag to avoid disclosing company proprietary data.

4/ Value is the selling price at plant and includes, for a few facilities, estimates reported by the plants and/or made by the U.S. Geological Survey.

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TABLE 2
AVERAGE VALUE AT THE PLANT FOR IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES, BY TYPE

(Dollars per metric ton)

Year	Iron blast furnace slag			Steel slag	Total slag
	Air-cooled	Expanded 1/	Total iron slag		
1999	6.50	32.00	11.00	3.92 r/	8.78 r/
2000	6.61	27.21	10.80	3.92	8.62

r/ Revised.
1/ Includes granulated slag to avoid disclosing company proprietary data.

TABLE 3
BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY REGION AND STATE 1/ 2/

(Million metric tons and million dollars)

Region and State	1999				2000			
	Air-cooled		Total, all types		Air-cooled		Total, all types	
	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
North-Central: Illinois, Indiana, Michigan, Ohio	5.3	34.80	6.3	53.60	4.9	32.00	5.8	50.00
Mid-Atlantic: Maryland, New York, Pennsylvania, West Virginia	1.9	13.30	2.8	56.80	2.1	15.60	3.2	55.00
Other 4/	1.8	10.10	1.8	10.10	1.9	11.20	2.2	16.00
Total	8.9	58.30	10.9	120.00	8.9	58.60	11.2	121.00

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imported slag.
3/ Value based on selling price at plant.
4/ Includes Alabama, California, Kentucky, Mississippi, and Utah.

TABLE 4
AIR-COOLED BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2/

(Million metric tons and million dollars)

Use	1999		2000	
	Quantity	Value 3/	Quantity	Value 3/
Asphaltic concrete aggregate	1.7	11.30	1.7	11.30
Concrete aggregate	1.2	8.60	1.2	8.70
Concrete products	0.3	1.70	0.2	1.50
Fill	1.1	5.20	0.8	3.90
Mineral wool	0.5	4.40	0.5	5.00
Railroad ballast	0.2	0.60	(4/)	(4/)
Road bases	3.0	16.70	3.3	18.40
Roofing, built-up and shingles	(4/)	0.50	(4/)	(4/)
Other 5/	1.0	9.30	1.2	9.80
Total	8.9	58.30	8.9	58.60

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imports.
3/ Value based on selling price at plant.
4/ Less than 1/2 unit.
5/ Includes cement, ice control, glass manufacture, sewage treatment, soil conditioning, and miscellaneous.

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TABLE 5
STEEL SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2/ 3/

(Million metric tons and million dollars)

Use	1999 r/		2000	
	Quantity	Value 4/	Quantity	Value 4/
Asphaltic concrete aggregate	1.0	5.30	0.9	5.00
Fill	1.0	3.40	1.0	3.00
Railroad ballast	1.2	0.30	0.4	1.10
Road bases	1.8	6.02	1.7	6.30
Other 5/	1.2	8.00	1.1	4.70
Total	6.2	23.00	5.1	20.10

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imports.
3/ Excludes tonnage returned to furnace for charge material.
4/ Value based on selling price at plant.
5/ Includes ice control, soil conditioning, and miscellaneous uses.

TABLE 6
AVERAGE AND RANGE OF SELLING PRICES AT THE PLANT FOR IRON AND STEEL SLAG IN THE UNITED STATES IN 2000, BY USE

(Dollars per metric ton)

Use	Iron blast furnace slag 1/		Steel slag	
	Average	Range	Average	Range
Asphaltic concrete aggregate	5.00	4.00-8.00	4.00	2.00-8.00
Concrete products	5.00	3.30-8.00	(2/)	(2/)
Fill	4.00	2.00-9.00	2.00	0.99-14.00
Mineral wool	7.00	4.00-10.00	W	(2/)
Railroad ballast	4.00	3.00-8.00	2.00	2.00-3.00
Road bases	5.00	1.00-8.00	3.00	2.00-12.00
Roofing, built-up and shingles	11.00	6.00-14.00	(2/)	(2/)
Other 3/	7.00	6.00-79.00	5.00	4.00-8.00

W Withheld to avoid disclosing company proprietary information.
1/ Air-cooled slag only. Price range breakouts, by use, for granulated and expanded slag are withheld to avoid disclosing proprietary information; overall, prices ranged from $2.00 to $8.00 per metric ton for iron and steel slag.
2/ No use reported.
3/ Includes cement manufacture, glass manufacture, sewage treatment, and soil conditioning.

TABLE 7
SHIPMENTS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2000, BY METHOD OF TRANSPORTATION 1/ 2/

(Million metric tons)

Method of transportation	Quantity
Truck	10.9
Rail	0.8
Waterway	2.2
Total	13.9
Not transported (used at plant)	2.4

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imported slag.

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TABLE 8
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2000

Company	Plant location	Steel slag			Iron slag	
		Basin oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Slag type
Blue Circle Cement Co.	Baltimore, MD	X			X	Granulated.
Buffalo Crushed Stone, Inc.	Buffalo, NY	X			X	Air cooled.
C.J. Langenfelder	Baltimore, MD	X				
Do.	Braddock, PA	X				
Edward C. Levy Co.	Detroit, MI	X		X	X	Air cooled and expandec
Heckett MultiServ Co.	Armorel, AR			X		
Do.	Fontana, CA	X			X	Air cooled.
Do.	Wilton, IA			X		
Do.	Chicago, IL			X		
Do.	Sterling, IL			X		
Do.	East Chicago, IN	X				
Do.	Indiana Harbor, IN	X				
Do.	Ashland, KY	X			X	Air cooled.
Do.	Coalton, KY			X		
Do.	Newport, KY			X		
Do.	Owensboro, KY			X		
Do.	Kansas City, MO			X		
Do.	Canton, OH			X		
Do.	Mansfield, OH	X				
Do.	Massillon, OH			X		
Do. (Warren Plant)	Warren, OH	X				
Do.	do.			X		
Do.	Youngstown, OH			X		
Do.	Butler, PA			X		
Do.	Provo, UT		X		X	Air cooled.
International Mill Services	Fort Smith, AR			X		
Do.	Kingman, AZ			X		
Do.	Pueblo, CO	X				
Do.	Claymont, DE			X		
Do.	Cartersville, GA			X		
Do.	Alton, IL			X		
Do.	Chicago, IL			X	X	Air cooled.
Do.	Kankakee, IL			X		
Do.	Gary, IN			X		
Do.	Huntington, IN			X		
Do.	Laplace, LA			X		
Do.	Jackson, MI			X		
Do.	Monroe, MI			X		
Do.	St. Paul, MN			X		
Do.	Jackson, MS			X		
Do.	Charlotte, NC			X		
Do.	Perth Amboy, NJ			X		
Do.	Riverton, NJ			X		
Do.	Sayreville, NJ			X		
Do.	Auburn, NY			X		
Do.	Hubbard, OH			X		
Do.	Marion, OH			X		
Do.	Mingo Junction, OH	X		X		
Do.	Warrent, OH			X		
Do.	McMinnville, OR			X		
Do.	Portland, OR			X		
Do.	Brideville, PA			X		
Do.	Coatesville, PA			X		
Do.	Holsopple, PA			X		
Do.	Houston, PA			X		
Do.	New Castle, PA			X		
Do.	Midland, PA			X		
Do.	Pricedale, PA	X		X		
Do.	Reading, PA	X		X		
Do.	Darlington, SC	X		X		
Do.	Georgetown, SC	X		X		
Do.	Jackson, TN	X		X		
Do.	Beaumont, TX	X		X		
Do.	El Paso, TX	X		X		
Do.	Jewett, TX	X		X		

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TABLE 8--Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2000

Company	Plant location	Steel slag			Iron slag	
		Basin oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Slag type
International Mill Services--Continued:	Longview, TX	X		X		
Do.	Plymouth, UT	X		X		
Do.	Seattle, WA	X		X		
Do.	Saukville, WI	X		X		
Do.	Weirton, WV	X		X		
Holnam Inc.	Gary, IN				X	Air cooled, granulated, eand xpanded.
Do.	Weirton, WV				X	Granulated.
IMS Waylite Corp.	Bethlehem, PA	X	X		X	Air cooled and expandec
Do.	Cambria, PA		X		X	Air cooled.
Lafarge Corp.	Cuyahoga, OH		X			do.
Do.	Lordstown, OH		X		X	Granulated.
Do.	McDonald, OH		X			
Do.	Mingo Junction, OH				X	Air cooled.
Do.	Warren, OH				X	do.
Do.	Youngstown, OH		X			
Do.	West Mifflin, PA				X	do.
Do.	Weirton, WV				X	do.
The Levy Co. Inc.	Burns Harbor, IN	X			X	do.
Do.	East Chicago, IN				X	do.
Martin Marietta Aggregates	Raleigh, NC	X			X	do.
Maryland Slag Co.	Baltimore, MD				X	do.
Olympic Mill Services	Seguin, TX			X		
Stein, Inc.	Decatur, AL	X				
Do.	Cleveland, OH	X			X	do.
Do.	Lorain, OH				X	do.
Vulcan Materials Co.	Alabama City, AL				X	do.
Do.	Fairfield, AL	X			X	do.

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SODA ASH

By Dennis S. Kostick

Domestic survey data and tables were prepared by Jeff Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Soda ash, also known as sodium carbonate (Na_2CO_3), is an alkali chemical refined from the mineral trona or naturally occurring sodium carbonate-bearing brines (both referred to as natural soda ash), the mineral nahcolite (referred to as natural sodium bicarbonate, from which soda ash can be produced), or manufactured from one of several chemical processes (referred to as synthetic soda ash).

Production

Soda ash production and inventory data were collected by the U.S. Geological Survey (USGS) from monthly, quarterly, and annual voluntary surveys of the U.S. soda ash industry. A survey request was sent to each of the six soda ash companies, all of which responded, representing 100% of the total production data in this report (table 1). The information and data are fundamental resources for analysis, both within and outside the government. The soda ash data and information are used by the public and private sectors to better understand minerals and materials usage and the ultimate disposition of materials in the economy and in the environment and to develop public and private sector policies and practices that better utilize our mineral and material resources. Some of the organizations that use the soda ash data and information are financial institutions, State and Federal agencies, soda-ash-consuming industries (e.g., glass, chemicals, and detergents), educational institutions, and the general public.

U.S. production of natural soda ash from California, Colorado, and Wyoming in 2000 was 10.2 million metric tons (Mt), which was virtually the same as that of 1999. Based on about 14.5 Mt (16 million short tons) of total nameplate capacity, the U.S. soda ash industry operated at 70% of total capacity. This capacity utilization rate appears low because it includes the full nameplate capacity of 900,000 metric tons (t) (1 million short tons) for American Soda, L.L.P., which began late in the year with minimal output but was included in the industry total because nameplate capacity is based on the industry total as of December 31 of each year. Furthermore, the capacity utilization rate was low because OCI Chemical Corp. and FMC Wyoming Corp. had idled about 820,000 t (900,000

Soda Ash in the 20th Century

The 20th century has been called the greatest century of industrial progress in the history of civilization. In that time, the world soda ash industry had emerged as an important component of the family of chlor-alkali producers. During the past 100 years, the world soda ash industry expanded rapidly to provide a multitude of new products for millions of users. As the century closed and the new millennium began, the world soda ash industry was undergoing a restructuring as competition increased from new sources and traditional end-use markets changed. The first natural soda domestic soda ash production increased to about 370,000 tons, of which only about 25,000 tons was natural soda ash. In 1900, the majority of U.S. soda ash production was synthetic soda ash produced by four companies operating a total of five plants at Detroit and Wyandotte, MI; Syracuse, NY; Barberton, OH; and Saltville, VA. Natural soda ash was produced from alkaline lakes by five companies operating a total of five plants in Keeler, CA (Owens Lake); Ragtown, NV (Big Soda Lake and Little Soda Lake); Schurz, NV (Double Springs Marsh); and Laramie, WY (Union Pacific Lakes).

Around the beginning of the 20th century, the estimated distribution of soda ash by end use was glass, 25%; sodium bicarbonate and sal soda, 25%; paper manufacture, 20%; soap and chemicals, 20%; and miscellaneous, 10%. Soda ash exports during this period were negligible. As the U.S. population continued to grow after 1900 and the demand for consumer products increased, soda ash production and consumption also increased.

By 2000, soda ash had already become a mature commodity with a growth rate that followed population growth and gross domestic product trends. The United States had become the world leader in production and trade. Soda ash production in 2000 was exclusively from natural sources; the last synthetic soda ash plant in the United States had closed in 1986. Ironically, this last plant was also the first one built in the country in 1884. The rising cost of energy, issues pertaining to pollution, and competition from natural soda ash were the factors that forced the closure of all the U.S. synthetic soda ash plants and many of the synthetic plants in the world leading up to 2000. The U.S. soda ash industry in 2000 consisted of six producers that mined sodium-carbonate-bearing deposits in California, Colorado, and Wyoming.

Glass was still the largest end use for soda ash in 2000, representing 50% of total domestic consumption. Soda ash was still used for soap and detergents and chemicals, as it was a century before; new uses such as flue gas desulfurization and water treatment also developed. The Belgian company Solvay S.A., which invented the Solvay synthetic soda ash production process and introduced it to the United States in 1884, competed with U.S. producers for most of the 20th century only to become a partner in the last decade and an important member of the U.S. soda ash industry in 2000.

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short tons) and 590,000 t (650,000 short tons), respectively, of available capacity until market conditions improved.

At the beginning of 2000, the U.S. soda ash industry consisted of five companies: four in Wyoming operating five plants that produced soda ash from underground trona ore and one in California that produced soda ash from sodium-carbonate-rich brines. A sixth company came on-stream in October that produced soda ash and sodium bicarbonate from underground nahcolite in Colorado. Nahcolite is a mineral that is naturally-occurring sodium bicarbonate (its name is derived from the chemical elements contained in sodium bicarbonate: Na (sodium), H (hydrogen), C (carbon), O (oxygen), and "lite" (stone).

Increasingly, foreign synthetic soda ash producers and consumers had become involved in the U.S. natural soda ash industry. In 2000, foreign investment in U.S. soda ash operations was 36% of total nameplate capacity. The six U.S. companies have partners from Belgium, Japan, and the Republic of Korea (table 2).

In October 2000, the newest U.S. soda ash facility began solution mining at an underground nahcolite deposit in the Piceance Creek Basin of Rio Blanco County in northwest Colorado. The company, American Soda, L.L.P., was formed in 1996 as a joint-venture partnership with Williams Soda Products Co., which was a wholly-owned subsidiary of The Williams Companies, Inc. (60%), and American Alkali, Inc. (40%). The water-soluble nahcolite was associated with oil shale on Federal sodium mineral leases. Hot water was injected into wells drilled to a depth of approximately 670 meters (m). A vertical cavern about 150 m to 180 m long was developed and topped with a cap of nitrogen gas to prevent further dissolution and spalling of the cavern roof. A sodium-bicarbonate-bearing solution was recovered and processed to remove the carbon dioxide gas, and the remaining sodium-carbonate-rich solution was pipelined 71 kilometers to the soda ash refinery at Parachute. On November 3, the first soda ash was produced at the plant. Although a small quantity of product was made for test purposes during the remainder of the year, the first commercial deliveries were not scheduled until January 2001. During its first year of production, the plant was scheduled to operate at a rate of about 545,000 metric tons per year (t/yr), but when fully operable, the facility will have a nameplate capacity of 900,000 t/yr of soda ash and about 135,000 t/yr of sodium bicarbonate.

Consumption

The USGS collects reported consumption data by end use on a quarterly basis from the marketing and sales departments of each company. Every effort has been made to categorize company sales within the correct end-use sector. Quarterly reports are often revised in subsequent quarters because of customer reclassifications or other factors. Because all U.S. soda ash companies responded to the quarterly survey, the data represented 100% of the total reported consumption data found in this report.

In 2000, U.S. apparent consumption of soda ash was 6.43 Mt; reported consumption, however, was 6.39 Mt (table 3). Reported consumption and apparent consumption data do not necessarily correspond because reported consumption data were based on actual sales, whereas apparent consumption data were the calculated quantity available for domestic consumption based on balancing supply (production, imports, and inventory adjustments) with external demand (exports).

In 2000, U.S. apparent consumption and reported consumption varied by 40,000 t, which was slightly less than 1% of apparent consumption. The discrepancy between the two forms of consumption was attributed to disagreement between the sources of export data used to derive consumption statistics. The two sources were the U.S. Census Bureau, which reports exports upon departure from U.S. ports, and the soda ash producers, which consider a shipment as exported when their export association, the American Natural Soda Ash Corp. (ANSAC), takes consignment of the product at the California, Colorado, or Wyoming plant sites. Transit times between the plant and port, which can take about 2 to 3 weeks before the cargo is actually exported, and carryover export inventories contribute to the discrepancy between reported and apparent consumption as well.

The distribution of soda ash by end use in 2000 was glass, 50%; chemicals, 27%; soap and detergents, 11%; distributors, 6%; flue gas desulfurization and pulp and paper, 2% each; and water treatment and other, 1% each.

Glass.—Glass manufacture represented about 50% of domestic soda ash consumption: the container sector accounted for 48%; flat, 36%; and specialty and fiber, 8% each. There were 57 glass container manufacturing plants in 24 States that produced a variety of different colored glass containers for various products. About 58% of the container market was clear (flint) glass; 35% was brown (amber) glass; 6% was green, and 1% was miscellaneous colors. The containers are made for beverages (beer, carbonated, and noncarbonated drinks), chemical and household products, food, liquor, medical products, and toiletries and cosmetics.

According to U.S. Census Bureau data, production of glass containers decreased by 3% to 8.56 Mt in 2000 from 8.85 Mt in 1999 primarily because of the beverage sector whose use of glass continued to decline because more soft drinks were packaged in plastic containers than in glass bottles. Production of glass containers for the beer industry increased by 1.9% to 4.04 Mt from 3.97 Mt in 1999. From 1980 to 2000, the output of glass beer containers varied between a low of 2.6 million metric tons per year (Mt/yr) to a high of 4.0 Mt/yr; however, the beer container sector composed 30% of the total quantity of glass containers manufactured in 1980, whereas it accounted for 52% of the sector in 2000. This increase is attributed to the decline in such other sectors as glass food containers [narrow neck (30)%, and wide mouth (26%)] during that time period, with glass food container production decreasing to 2.0 Mt in 2000 from 3.6 Mt in 1980. Production of beverage containers also declined; however, a large amount of data had been withheld since 1996, which made it difficult to accurately determine how much of a decrease there has been since 1980, when beverage containers accounted for 19% of all glass containers.

Although the domestic glass recycling rate was not published for 1999 or 2000, it is assumed the recycling rate remained the same as that of 1998, which was 35%. Of that, 24% was

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estimated to be post-consumer cullet and the remainder being in-house scrap. Some municipalities had started terminating their glass-collection programs because the price of clean, sorted cullet had declined, thereby making it less attractive to recyclers. Another reason was that breakage during collection had affected the quality of material sold to glass container manufacturers.

In March 2000, Miller Brewing Co. and Continental PET Technologies announced they developed a new plastic bottle for beer for widespread distribution. The bottle had been test-marketed since October 1998 in six major cities, and consumer acceptance was favorable. The benefits of the new container were that it kept the beer colder than aluminum cans and as long as glass bottles, was one-seventh the weight of comparable glass containers, was unbreakable, and was recyclable with other polyethylene terephthalae (PET) containers. The PET beer bottle was accepted in areas where glass bottles were not allowed or were as convenient, such as stadiums, pools, concerts, and beaches (Miller Brewing Co., 2000).

In July, a new PET resin was introduced for beer and other hot-fill applications by KoSa. KoSa was formed in December 1998 when Koch Industries, Inc. (through its subsidiaries Koch International Equity Investments B.V. and Koch Equity Investments, Inc.), and IMASAB S.A. de C.V. purchased the polyester business of Hoechst Aktiengesellschaft. The new plastic beer container provides a lightweight, thermally stable bottle that allows the beer to be pasteurized in the bottle, which up to this time could only be done with glass bottles. The PET bottle also can be used for carbonated soft drinks, water, juice, food, and custom container applications (KoSa, 2000).

Chemicals.—Soda ash is used to manufacture many sodium-base inorganic chemicals, including sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates.

According to data from the U.S. Census Bureau, production of sodium bicarbonate decreased by 4% to 486,000 t in 2000 from 505,000 t in 1999 (U.S. Census Bureau, 2000).

In addition to American Soda, which began producing soda ash and sodium bicarbonate from Colorado nahcolite, AmerAlia, Inc., received approval of its environmental assessment from the Bureau of Land Management to proceed with the planned construction of a 68,000 t/yr (75,000-short-ton-per-year) sodium bicarbonate plant in Colorado. AmerAlia's partner, U.S. Filter, Inc., drilled three of the five groundwater monitoring wells around the mine site that will detect any excursion of sodium-bicarbonate-bearing solutions from the solution mined caverns. U.S. Filter was financing 80% of the $40 million project with AmerAlia securing the remaining 20% financing. Startup was scheduled for sometime in 2001 (Industrial Minerals, 2000a).

Soaps and Detergents.—Detergents were the third largest use of soda ash. Soda ash was used as a builder to emulsify oil stains, to reduce the redeposition of dirt during washing and rinsing, to provide alkalinity for cleaning, and to soften laundry water. In addition, soda ash was a component of sodium tripolyphosphate (STPP), another major builder in detergent formulations. Soda ash consumption has been decreasing because phosphatic detergents can contribute to eutrophication, which is an environmental concern. Many regions of the Nation adopted phosphate limitations or bans, affecting about 40% of the U.S. population. A strong U.S. economy boosted demand for industrial and institutional cleaners and automatic dishwashing detergents in the past couple of years. New technology incorporating enzymes in dishwashing detergents and a move toward liquid cleansers, however, may adversely affect STPP consumption in the future.

In response to the environmental concern that cardboard detergent packaging contributes to the volume of landfill waste, detergent manufacturers changed formulations to make compact and superconcentrated products. These reformulations required sodium silicates and synthetic zeolites, which are made from soda ash. Liquid detergents, which do not contain any soda ash, competed with powdered detergents and commanded about 50% of the household laundry detergent market in 2000 compared with 15% in 1978.

Stocks

Yearend 2000 stocks of dense soda ash in domestic plant silos, warehouses, terminals, and on teamtracks amounted to 245,000 t. Producers indicated that a potential supply problem could exist if inventories fell below 180,000 t. Most consumers of soda ash did not have the storage facilities to accommodate large quantities of soda ash and had to rely on suppliers to provide the material on a timely basis.

Prices

In the domestic market, large-volume buyers of soda ash were primarily the major glass container manufacturers whose purchases were seasonal (more beverage containers made in the second and third quarters for summertime beverage consumption). Soda ash sales to the flat glass sector were usually dependent on the state of the economy because the largest use of flat glass was in automobile manufacture and in residential housing and commercial building construction. These two major industrial sectors were especially sensitive to changing economic conditions, and soda ash sales follow trends in the two sectors.

The average annual value for bulk, dense natural soda ash, free-on-board (f.o.b.) Green River, WY, and Searles Valley, CA, was $73.00 per metric ton ($66.23 per short ton), which was a 4% decrease compared with that of 1999. No value data were collected from the Colorado producer because the majority of its yearend output was for test purposes and not for commercial customers. The value is not a price but rather the value of the combined revenue of California and Wyoming bulk, dense soda ash sold on an f.o.b. plant basis at list, spot, or discount prices, on long-term contracts, and for export, divided by the quantity of soda ash sold. The list prices quoted in trade journals or by producers differed from the annual average values reported to and by the USGS. This value may or may not correspond to the posted list prices. The list price for Wyoming bulk, dense soda ash has not changed since it was raised effective July 1, 1995, or as contracts permit, to $105 per short ton from $98 per ton. The California price for the comparable product also increased by $7 per short ton, to $130 per ton from $123 per ton (table 4).

FMC announced a soda ash price increase of $5 per short ton

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on August 31, effective October 1 or as contracts permit. The company stated that the increase was necessary in order to bring prices to reinvestment levels and to offset rising energy costs. Despite an oversupply of soda ash in the market, FMC forecasted export sales would increase and certain caustic soda customers would switch to soda ash so long as caustic soda prices were high (Chemical Week, 2000a). One week later, OCI Chemical and Solvay Minerals Inc. followed FMC and announced a $5 per short ton price increase (Chemical Week, 2000c). General Chemical Corp. was the next to follow, on September 27, with its $5 price increase (Chemical Week, 2000d); IMC Chemical Co. announced in early October that it would raise its soda ash prices by $5 effective immediately or as contracts permit (Chemical Week, 2000b). The industry indicated that the price increase attempt was in response to an improving supply-demand balance for soda ash during the fourth quarter of 1999. General Chemical issued another $5 per short ton price increase effective December 1 that was followed by FMC, which also raised its price by another $5 per short ton on all grades of soda ash including bulk, bagged, and all material sold through distribution centers, warehouses, and transloaders (Chemical Market Reporter, 2000b). Although there was some success in raising prices in the spot market, the full effect of the increase attempt would not be noticeable until 2001, because 90% of domestic sales were on annual contracts renewable each January.

Foreign Trade

Exports of 3.90 Mt represent about 38% of U.S. soda ash production. The problems in the Asian economies that began in late 1997 continued through 1999 and into 2000. An upturn in the economies in most of the nations, however, was evident by mid-2000, and U.S. soda ash exports began to increase. In 2000, Asia received 44% of the U.S. soda ash exported, accounting for 17% of total domestic output, compared with 38% of total U.S. soda ash exported in 1999 representing 14% of domestic production. The economic problems lasted longer than most market analysts had forecasted, resulting in delays in several domestic soda ash capacity expansions. In 2000, China increased its soda ash production by 9% compared with that of 1999, to 8.34 Mt from 7.65 Mt. Increases in Chinese soda ash production, industry rationalization, and improving economic conditions in Asia may affect the U.S. soda ash export market (Chemical Market Reporter, 2000c).

The U.S. soda ash industry exported the majority of its soda ash through its export association, ANSAC. Because of rising energy and transportation costs, ANSAC raised its selling price by $10 per metric ton, effective November 1 (Chemical Market Reporter, 2000a).

After 2 years of declining export sales, U.S. soda ash exports in 2000 were 3.90 Mt, which was 8% greater than that of 1999. In 2000, U.S. exports to 47 countries, on a regional basis, were as follows: Asia, 44%; North America and South America, 21% each; Europe and the Middle East, 4% each; Africa and Oceania, 2% each; and Central America, 1% (table 6). Shipments to the Caribbean were negligible. The average free-alongside-ship value was $122.52 per ton in 2000 compared with $123.48 per ton in 1999. Although the data in tables 1 and 6 are rounded to three significant digits, the unit values shown are based on the actual unrounded statistics and not the rounded data. The top 10 countries, representing 72% of total U.S. soda ash exports, in decreasing order and percent of total, were: Mexico, 16%; the Republic of Korea, 10%; Japan, 9%; Brazil, 7%; Indonesia, 6%; Taiwan, 5%; Venezuela, 5%; Chile, 4%; and Thailand, 4%. About 57% of all U.S. soda ash exports went through the Columbia-Snake River customs district; the Laredo, TX, customs district was the second largest, with 15% of the total (table 5).

Imports of soda ash decreased by 18% to 75,000 t. The majority (99%) came from Canada, where General Chemical operated a synthetic soda ash plant in Amherstburg, Ontario. The remainder was imported from Bulgaria, Hong Kong, Italy, Japan, Mexico, Turkey, and the United Kingdom. The average customs-insurance-freight value of imported soda ash was $114.32 per ton.

World Review

The largest consumers of soda ash were, for the most part, developed nations; these countries, however, also usually have lower growth rates compared with developing countries, which usually have greater demands for consumer products. Although the production and consumption quantities varied among the countries, the end-use patterns were basically the same; glass, chemicals, and detergents were the major sectors (table 8).

Nine countries had the capacity to produce more than 1 Mt/yr. They are, in descending order, the United States, China, Russia, India, Germany, France, Italy, Poland, and the United Kingdom. Bulgaria, Romania, and Ukraine had production installations that were rated at about 1 Mt/yr; adverse economic conditions, however, had caused these nations to produce below their design capacities. Recent acquisitions or joint ventures with major European soda ash producers that have soda ash manufacturing expertise should reverse this situation in the next few years. Most of these soda-ash-producing countries have large populations that require consumer products made with soda ash. The less developed nations tend to have higher soda ash demands and higher growth rates as soda-ash-consuming industries are developed. In 2000, world soda ash production was estimated to be 34.2 Mt, which was a 3% increase compared with that of 1999.

Canada.—Overcapacity, high energy costs, and low profitability were cited as reasons why General Chemical announced it would close its synthetic soda ash plant in Amherstburg, Ontario, in April 2001 and would reopen the plant when market conditions improved. The plant, which was built in 1919, had a nameplate capacity of 500,000 t/yr (Chemical and Engineering News, 2000).

Germany.—IMC Chemicals closed its synthetic soda ash plant in Duisburg in January 2000. The plant was formerly owned by Matthes & Weber GmbH and had a capacity of 280,000 t/yr, which was about 5% of the European soda ash industry capacity (Industrial Minerals, 2000d).

India.—ANSAC filed a petition with the U.S. Trade Representative to suspend the Generalized System of Preferences for India until there was progress toward fair and equitable access to Indian soda ash markets. The import tariff

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on soda ash was 38.5%, which was the highest in the world, and other import fees brought the total to 69.9%. Reports indicated that the tariffs would have to be reduced to 12% before U.S. soda ash could be competitive, bringing the net effective import fee to 38.92%, which would include the 12% tariff, a 10% surcharge, an 18% countervailing duty tax, and special import fees (North American Mineral News, 2000).

Japan.—Asahi Glass Co., Ltd., announced it planned to permanently close its synthetic soda ash plant in Kitakyushu by the end of the first quarter of 2001. The decision to close the plant was based on the large capital expenditure required to modernize the facility and the company's investment in the U.S. soda ash industry. Through its subsidiary AG Soda Corp., Asahi has a 20% partnership with Solvay Minerals in its Wyoming operation (Industrial Minerals, 2000b).

Pakistan.—ICI Pakistan, Ltd., which was owned by ICI plc (76%) and private investors (24%), announced a $10 million expansion at its synthetic soda ash plant in Khewara, northern Punjab. The expansion would increase the facility's capacity from 190,000 t/yr to 225,000 t/yr. The operation supplied about 80% of the domestic soda ash requirements of the country's detergent, glass, and paper industries (Industrial Minerals, 2000c).

Outlook

As the 20th century drew to a close, the number of producers in the world soda ash industry became smaller because of the closures of many synthetic soda ash plants in Europe, South America, and Asia during the 1990s. At the beginning of the new millennium, three dominant groups have survived to become the world leaders in soda ash—Solvay S.A. of Belgium, ANSAC of the United States (which represents all six domestic producers), and the Chinese soda ash industry. In years to come, these three soda ash suppliers will produce and export soda ash to many customers all over the world. Because the glass container sector is the largest soda-ash-consuming sector, the demand for soda ash for glass containers may decline as consumers slowly accept their food and beverages packaged in the newer PET containers.

The outlook for soda ash for the next 5 years is favorable. Domestic soda ash is expected to grow between 0.5% and 1.0% per year, and world demand is forecast to range from 2.0% to 2.5% per year for the next several years. Asia and South America remain the likeliest areas for increased soda ash consumption in the near future.

References Cited

U.S. Census Bureau, 2000, Current industrial reports—Inorganic chemicals: Bureau of the Census, MQ325A (99) 1-4, April 2001, 6 p.

Chemical and Engineering News, 2000, General Chemical ends era with Solvay plant closure: Chemical and Engineering News, v. 78, no. 50, December 11, p. 35.

Chemical Market Reporter, 2000a, Soda ash: Chemical Market Reporter, v. 258, no. 181, October 30, p. 34.

———2000b, Soda ash producers seek to recover value in difficult market conditions: Chemical Market Reporter, v. 258, no. 25, December 18, p. 5.

———2000c, Sodium bicarbonate market braces for the entrance of American Soda: Chemical Market Reporter, v. 258, no. 12 , September 18, p. 5.

Chemical Week, 2000a, FMC leads soda ash price increases: Chemical Week, v. 162, no. 34, September 13, p. 19

———2000b, IMC raises soda ash: Chemical Week, v. 162, no. 39, October 18, p. 51

———2000c, Soda ash advances: Chemical Week, v. 162, no. 35, September 20, p. 43.

———2000d, Soda ash advances: Chemical Week, v. 162, no. 37, October 4, p. 31.

Industrial Minerals, 2000a, AmerAlia's nahcolite mine gets go-ahead: Industrial Minerals, no. 390, March, p. 25.

———2000b, Asahi Glass to cease soda ash output: Industrial Minerals, no. 393, June, p. 14.

———2000c, ICI to increase soda ash capacity by 18%: Industrial Minerals, no. 394, July, p. 15.

———2000d, Soda ash and fertiliser closures for IMC: Industrial Minerals, no. 388, January, p. 15.

KoSa, 2000, KoSa launches innovative resin for beer and hot-fill markets: KoSa news release, July 26, 1p.

Miller Brewing Co., 2000, Forget the green beer this St. Patrick's day—Miller announces national rollout of plastic bottles: Miller Brewing Co. press release, March 9, 2 p.

North American Mineral News, 2000, US turns up the heat on Indian soda ash: North American Mineral News, no. 58, March, p. 16.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Soda Ash. Ch. in Mineral Commodity Summaries, annual.
Soda Ash. Ch. in Minerals Yearbook, annual.
Soda Ash. Mineral Industry Surveys, monthly.

Other

Chemical and Engineering News.
Chemical Marketing Reporter.
Chemical Week.
Engineering and Mining Journal, commodities survey.
Industrial Minerals (London).
Manufacture of Soda. Te-Pang Hou, American Chemical Society Monograph Series, 1942.
Natural Soda Ash. D.E. Garrett, Van Nostrand Reinhold, 1st ed., 1992.
Proceedings of the International Soda Ash Conference—Volumes 1 and 2. J.R. Dyni and R.W. Jones, eds., 1998.
Soda Ash. Ch. in Industrial Minerals and Rocks, Society of Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Soda Ash. Mining Engineering, annual review of industrial minerals.
Soda Ash and Sodium Sulfate. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT SODA ASH STATISTICS 1/

(Thousand metric tons and thousand dollars, except value per ton)

	1996	1997	1998	1999	2000
United States:					
Production 2/	10,200	10,700	10,100	10,200	10,200
Value 2/	$926,000	$915,000	$842,000	$779,000	$748,000
Value, average annual:					
Per short ton	$82.60	$77.25	$75.30	$69.11	$66.23
Per metric ton	$91.05	$85.15	$83.00	$76.00	$73.00
Production, Wyoming trona	16,300	17,100	16,500	15,900	15,700
Exports	3,840	4,190	3,660	3,620	3,900
Value	$508,000	$547,000	$478,000	$447,000	$477,000
Imports for consumption	107	101	83	92	75
Value	$14,700	$13,400	$10,800	$11,100	$8,570
Stocks, December 31, producers'	271	259	273	248	245
Consumption:					
Apparent	6,480 r/	6,670	6,560	6,740	6,430
Reported	6,390	6,480	6,550	6,430	6,390
World, production	31,800	33,100	32,400 r/	33,200 r/	34,200 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except value per ton.

2/ Natural only; soda liquors and purge liquors are withheld to avoid disclosing company proprietary data.

TABLE 2
U.S. PRODUCERS OF SODA ASH IN 2000

(Million short tons, unless otherwise noted)

Company	Plant nameplate capacity	Plant location	Source of sodium carbonate
American Soda, L.L.P. 1/	1.00	Parachute, CO	Underground nahcolite.
FMC Wyoming Corp. - Green River 2/	3.55	Green River, WY	Underground trona.
FMC Wyoming Corp. - Granger 3/	1.30	Granger, WY	Do.
General Chemical (Soda Ash) Partners 4/	2.80	Green River, WY	Do.
IMC Chemical Co. 5/	1.45	Trona, CA	Dry lake brine.
OCI Chemical Corp. 6/	3.10	Green River, WY	Underground trona.
Solvay Minerals Inc. 7/	2.80	do.	Do.
Total	16.00		
Total million metric tons	14.50		

1/ Came on-stream October 2000. A joint venture with Williams Sodium Products Co., which is a subsidiary of The Williams Companies, Inc. (60%), and American Alkali, Inc. (40%).

2/ Formed joint venture (20%) in February 1996 with Sumitomo Corp. and Nippon Sheet Glass Co., Ltd., both of Japan.

3/ Tg Soda Ash Inc. was sold to FMC Wyoming Corp. in July 1999.

4/ A joint venture between General Chemical Corp. (51%), Owens-Illinois, Inc. [acquired Australian Consolidated Industries International (ACI) in 1998] (25%), and TOSOH Wyoming Inc. of Japan (24%), which purchased part of ACI's share in June 1992. An expansion was completed in 1998.

5/ IMC Global, Inc., acquired North American Chemical Co. in April 1998; operation renamed.

6/ Rhône-Poulenc Basic Chemicals Co. of France sold its 51% share to Oriental Chemical Industries Chemical Corp. of Korea on February 29, 1996; Anadarko Petroleum Corp. (acquired Union Pacific Resources Co. in 2000) owns 49%. An 800,000-metric-ton expansion, brought on-stream in November 1998, increased plant capacity to 3.1 million short tons; however, the company planned to take 900,000 metric tons out of service temporarily for equipment refurbishment.

7/ Solvay Soda Ash Joint Venture is owned by Solvay S.A. of Belgium (80%) and Asahi Glass Co. of Japan (20%), which became a partner in February 1990. Capacity increase of 272,000 metric tons (300,000 short tons) installed December 1995 and 454,000 metric tons (500,000 short tons) in October 2000.

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TABLE 3
REPORTED CONSUMPTION OF SODA ASH IN THE UNITED STATES, BY END USE, BY QUARTERS 1/

(Metric tons)

SIC code	End use	1999	2000				
			First quarter	Second quarter	Third quarter	Fourth quarter	Total
32	Glass:						
3221	Container	1,620,000	381,000	401,000	378,000	368,000	1,530,000
3211	Flat	1,130,000	272,000	290,000	288,000	304,000	1,150,000
3296	Fiber	263,000	62,200	62,500	60,000	62,100	247,000
3229	Other	254,000	61,800	63,000	58,600	56,500	240,000
	Total	3,270,000	777,000	817,000	785,000	791,000	3,170,000
281	Chemicals	1,670,000	404,000	421,000	439,000	455,000	1,720,000
284	Soaps and detergents	729,000	171,000	180,000	190,000	175,000	715,000
26	Pulp and paper	121,000	30,800	29,000	25,400	28,500	114,000
2899	Water treatment 2/	104,000	21,200	21,800	26,400	20,400	89,800
	Fluegas desulfurization	130,000	29,400	27,700	30,600	32,900	121,000
	Distributors	329,000	92,000	98,700	95,600	85,400	372,000
	Other	75,300	20,100	18,500	19,800	32,700	91,100
	Total domestic consumption 3/	6,430,000	1,550,000	1,610,000	1,610,000	1,620,000	6,390,000
	Exports 4/	3,850,000	841,000	1,030,000	1,050,000	1,080,000	4,010,000
	Canada	242,000	49,100	49,600	44,200	59,500	202,000
	Total industry sales 5/	10,300,000	2,390,000	2,650,000	2,660,000	2,700,000	10,400,000
	Total sales from plants	10,100,000	2,290,000	2,640,000	2,600,000	2,690,000	10,200,000
	Total production	10,200,000	2,390,000	2,530,000	2,580,000	2,740,000	10,200,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes soda ash equivalent from soda liquors and purge liquors sold to powerplant for water treatment. Sales of mine water are excluded.
3/ Imports reported by the producer/importer have been distributed into appropriate end-use categories listed above.
4/ Includes Canada. As reported by producers; may not necessarily agree with that reported by the U.S. Census Bureau for the same periods.
5/ Represents soda ash from domestic origin (production and inventory changes) and imports and for exports. Includes soda ash sold by coproducers and distributed by purchasers into appropriate end-use categories.

TABLE 4
SODA ASH YEAREND PRICES

(Dollars per short ton)

	1999	2000
Sodium carbonate (soda ash):		
Dense, 58% Na_2O 100-pound, paper bags, carlot, works, f.o.b.	153.00	153.00
Bulk, carlot, same basis, tons	105.00	105.00
Light 58% 100-pound, paper bags, carlot, same basis	210.00	210.00
Bulk, carlot, same basis, tons	173.00	173.00

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials, v. 257, no. 1, January 3, 2000, p. 24; and v. 259, no. 1, January 1, 2001, p. 21.

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TABLE 5
REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS, IN 2000 1/

(Metric tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percentage of total
Atlantic:											
Baltimore, MD	--	--	--	--	313	--	--	5	--	318	(2/)
Miami, FL	--	--	40	302	--	--	284	--	--	626	(2/)
New York, NY	--	--	--	--	410	23	--	30	--	463	(2/)
Savannah, GA	--	--	--	--	--	--	--	364	--	364	(2/)
Gulf:											
Houston-Galveston, TX	--	--	806	354	20	--	35	--	--	1,220	(2/)
Port Arthur, TX	--	2,010	240,000	10,800	--	--	84,700	--	--	337,000	9
Pacific:											
Columbia-Snake River	--	35,800	265,000	--	163,000	138,000	--	1,530,000	72,000	2,210,000	57
Los Angeles, CA	--	--	--	--	--	--	--	746	--	746	(2/)
San Diego, CA	12,400	--	328,000	--	4,850	--	--	166,000	14,100	525,000	13
San Francisco, CA	--	--	--	--	19	--	--	--	--	19	(2/)
Seattle, WA	24,100	--	--	--	--	--	--	--	--	24,100	1
North-central:											
Chicago, IL	--	--	--	--	36	--	--	--	--	36	(2/)
Detroit, MI	136,000	--	--	--	326	--	--	--	--	136,000	3
Duluth, MN	767	--	--	--	--	--	--	--	--	767	(2/)
Great Falls, MT	16,500	--	--	--	--	--	--	--	--	16,500	(2/)
Pembina, ND	6,430	--	--	--	--	--	--	--	--	6,430	(2/)
Northeast:											
Buffalo, NY	16,800	--	--	--	--	--	--	--	--	16,800	(2/)
Ogdensburg, NY	1,220	--	--	--	--	--	--	--	--	1,220	(2/)
St. Albans, VT	91	--	--	--	--	--	--	--	--	91	(2/)
Southwest:											
El Paso, TX	1,260	--	--	--	--	--	--	--	--	1,260	(2/)
Laredo, TX	598,000	--	--	--	--	--	--	--	--	598,000	15
Unknown:	21,700	--	--	--	--	--	--	--	--	21,700	1
Total	835,000	37,800	834,000	11,400	169,000	138,000	85,000	1,700,000	86,100	3,900,000	100
Percentage of total	21	1	21	(2/)	4	4	2	44	2	100	XX

XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

Source: U.S. Census Bureau. Reviewed by the U.S. Geological Survey using trade data and information from the Journal of Commerce.

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TABLE 6
U.S. EXPORTS OF SODA ASH, BY COUNTRY 1/

Country	1999 Quantity (thousand metric tons)	1999 Value 2/ (thousands)	1999 Unit value	2000 Quantity (thousand metric tons)	2000 Value 2/ (thousands)	2000 Unit value
Argentina	114	$15,800	$139.08	114	$16,200	$142.54
Australia	45	5,370	118.66	64	8,460	132.22
Belgium	118	14,500	123.36	60	7,290	121.55
Bolivia	2	426	173.48	2	271	135.50
Brazil	301	39,300	130.61	261	36,200	138.86
Canada	259	21,400	82.82	223	20,000	89.87
Chile	150	21,800	145.46	165	23,800	144.06
China	40	3,230	81.10	135	11,600	86.23
Colombia	73	10,300	140.50	82	12,600	153.20
Costa Rica	9	1,440	160.19	17	2,680	157.53
Ecuador	5	646	129.00	10	1,430	143.40
France	84	9,430	112.18	47	4,940	105.04
Germany	1	71	109.96	--	--	--
Guatemala	16	2,660	165.12	17	2,840	167.12
Indonesia	272	33,600	123.65	243	26,200	108.02
Italy	5	688	135.00	10	925	92.50
Jamaica	5	914	188.83	2	288	144.00
Japan	312	41,400	132.48	353	45,500	128.84
Korea, Republic of	227	30,600	134.52	390	48,200	123.69
Malaysia	95	13,400	141.29	117	15,500	132.66
Mexico	545	60,200	110.57	612	67,500	110.22
New Zealand	21	2,310	108.89	22	2,390	108.55
Nigeria	8	792	100.83	9	4,480	497.89
Pakistan	--	--	--	10	1,180	118.10
Panama	--	--	--	4	556	139.00
Peru	20	2,980	152.25	15	2,220	147.80
Philippines	64	8,320	129.50	74	8,740	118.12
Portugal	5	658	130.00	5	671	134.20
Saudi Arabia	92	8,950	97.29	117	10,800	92.44
Singapore	16	1,980	127.87	13	1,420	108.92
South Africa	84	10,600	127.08	76	9,960	131.00
Spain	100	10,300	103.13	40	4,160	104.03
Taiwan	157	20,200	128.26	186	23,600	126.95
Thailand	194	26,900	138.76	163	19,100	117.28
Trinidad and Tobago	11	1,930	170.42	9	1,400	156.00
United Arab Emirates	18	1,600	88.83	21	1,790	85.05
United Kingdom	8	1,100	144.82	6	856	142.67
Uruguay	1	116	146.60	--	--	--
Venezuela	138	20,000	145.03	185	29,700	160.56
Vietnam	9	783	87.00	15	1,460	97.13
Other 3/	1	113 r/	113.00 r/	1	256	256.00
Total	3,620	447,000	123.34	3,900	477,000	122.52

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

2/ F.a.s. value.

3/ Includes Aruba (2000), The Bahamas (1999), the Dominican Republic (2000), Finland (2000), Ghana (2000), Hong Kong (2000), Norway, Russia, Suriname (1999), Switzerland (2000), and Tonga (1999).

Source: U.S. Census Bureau. Reviewed by the U.S. Geological Survey using Journal of Commerce trade data and information.

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TABLE 7
U.S. PRODUCTION OF SODIUM COMPOUNDS, BY MONTH 1/

(Thousand metric tons)

	1999		2000	
	Soda ash	Wyoming trona 2/	Soda ash	Wyoming trona 2/
January	835	1,490	809	1,380
February	749	1,230	740	1,330
March	877	1,480	841	1,390
April	833	1,320	839	1,290
May	886	1,450	810	1,220
June	859	1,370	881	1,230
July	911	1,140	871	1,110
August	803	1,180	875	1,400
September	824	1,280	835	1,350
October	888	1,290	966	1,490
November	899	1,290	897	1,310
December	884	1,350	880	1,220
Total	10,200	15,900	10,200	15,700

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes solution-mined trona.

TABLE 8
SODA ASH: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1996	1997	1998	1999	2000
Australia	300	300	300	300	300
Austria	200	150	150	150	150
Bosnia and Herzegovina	15	15	15	15	15
Botswana	119 3/	200 3/	196 3/	234 r/ 3/	225
Brazil	200	200	200	200	200
Bulgaria	800 3/	800	800	800	800
Canada	300	300	300	300	300
China	6,693 3/	7,258 3/	7,440 3/	7,654 3/	8,343 3/
Egypt	50 r/	50 r/	50	50	50
France	1,100	1,053 3/	1,000	1,000	1,000
Germany	1,400	1,400	1,400	1,400	1,400
India	1,500	1,500	1,500	1,500	1,500
Italy	1,100 3/	1,000	1,000	1,000	1,000
Japan	926 3/	801 3/	722 3/	722 r/ 3/	685
Kenya 4/	223	258 3/	243 3/	246 r/ 3/	246
Korea, Republic of	320	320	300	310 r/	310
Mexico	290	290	290	290	290
Netherlands	400	400	400	400	400
Pakistan	215 3/	220	220	230	230
Poland	909 3/	950 3/	1,000	926 r/ 3/	950
Portugal	150	150	150	150	150
Romania	537 3/	548 3/	550	550	550
Russia	1,449 r/ 3/	1,652 r/ 3/	1,538 r/ 3/	1,918 r/ 3/	2,199 3/
Spain	500	500	500	500	500
Taiwan	128	128	126 r/	140 r/	140
Turkey	400	500 3/	500	500	500
Ukraine	375	367 3/	390	460 3/	500
United Kingdom	1,000	1,000	1,000	1,000	1,000
United States 4/	10,200 3/	10,700 3/	10,100 3/	10,200 3/	10,200 3/
Total	31,800	33,100	32,400 r/	33,200 r/	34,200

r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through April 19, 2001. Synthetic unless otherwise specified.
3/ Reported figure.
4/ Natural only.

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STONE, CRUSHED

By Valentin V. Tepordei

Domestic survey data and tables were prepared by Susan M. Copeland and John G. Durand, statistical assistants.

Crushed stone, one of the most accessible natural resources, is a major basic raw material used by construction, agriculture, and other industries that use complex chemical and metallurgical processes. Despite the low value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well-being of the Nation.

A total of 1.56 billion metric tons (Gt) of crushed stone was produced for consumption in the United States in 2000, a 30-million-metric-ton (Mt) or 2.0% increase compared with the total production of 1999. This tonnage represents the highest production level ever recorded in the United States, indicating a continued increase in the demand for construction aggregates (table 1).

About 70% of crushed stone production continued to be limestone and dolomite, followed, in descending order of tonnage, by granite, traprock, sandstone and quartzite, miscellaneous stone, marble, slate, calcareous marl, shell, and volcanic cinder and scoria (table 2).

Foreign trade of crushed stone continued to remain small. Exports decreased by 2.4% to 4 Mt, and their value decreased by 3.6% to $29.7 million compared with that of 1999 (table 25).

Imports of crushed stone, including calcium carbonate, increased by 5.7% to 13 Mt, but the value decreased by 0.5% to $105 million (table 26). Domestic apparent consumption of crushed stone, which is defined as production for consumption (sold or used) plus imports minus exports, was 1.57 Gt (tables 1, 25, 26).

Legislation and Government Programs

The Aviation Investment and Reform Act for the 21st Century (Public Law 106-181) was signed by the President on April 5, 2000. The law is a 3-year reauthorization of Federal Aviation Administration (FAA) programs and releases an estimated $1.9 billion in fiscal year 2000 for the Airport Improvement Program (AIP). In the following 3 years, the AIP funding will increase as follows: to $3.2 billion in fiscal year 2001, $3.3 billion in fiscal year 2002, and $3.4 billion in fiscal year 2003. In addition to the AIP, funds are also included for air traffic control improvements, airport security, noise abatement programs, and environmental streamlining programs. The law restructures and reauthorizes programs of the FAA and ensures that the taxes travelers pay on airline tickets are used to maintain the aviation system as originally intended.

On September 13, 2000, the Mine Safety and Health Administration (MSHA) regulation named "Health Standards for Occupational Noise Exposure—30 CFR Parts 56, 57, 62, 70, and 71" became effective. This final comprehensive rule replaced MSHA's previous standards for occupational noise exposure in coal mines and metal and nonmetal mines. The final rule established uniform requirements to protect the Nation's miners from occupational noise-induced hearing loss. The rule is derived in part from existing MSHA noise standards and from the Department of Labor's existing occupational noise exposure standard for general industry promulgated by the Occupational Safety and Health Administration. As a result of the ongoing review of its safety and health standards, the MSHA determined that its noise standards, which were more than 20 years old, did not adequately protect miners from occupational noise-induced hearing loss.

On October 2, 2000, the MSHA final rule titled "Training and Retraining of Miners Engaged in Shell Dredging or Employed

Crushed Stone in the 20th Century

At the beginning of the 20th century, the production of crushed stone in the United States was relatively small, and the uses of this resource were limited. At that time, records of stone production were kept on the basis of value, without recording the tonnages produced and without making a distinction between crushed and dimension stone. The value of all stone produced in the United States in 1900 was $43.8 million. In 1916, the U.S. Geological Survey reported for the first time quantities as well as values of domestic crushed stone production—77 million metric tons worth $50 million. In 1900, stone was used for construction purposes, mainly roads and buildings, for cement and lime manufacturing, for agricultural purposes as a soil treatment agent, and as flux stone in steel manufacturing. Stone production was reported in all 45 States. Leading States, in order of total value of production, were Pennsylvania, Vermont, Ohio, New York, and Maine. Vermont and Maine were among the top 5 States, probably because a significant amount of dimension stone, which was always more valuable than crushed stone, was being produced in those States.

In 2000, a total of 1.56 billion metric tons of crushed stone valued at $8.4 billion was produced in the United States for consumption, the highest production level ever recorded, indicating a continued increase in the demand for construction aggregates. About 70% of the crushed stone produced was limestone and dolomite, followed, in descending order of tonnage, by granite, traprock, sandstone and quartzite, miscellaneous stone, marble, slate, calcareous marl, shell, and volcanic cinder and scoria. About 84% of the total crushed stone produced by 1,500 companies operating 3,800 active quarries in 49 States was used as construction aggregates, mostly for highway and road construction and maintenance; 13%, for chemical and metallurgical uses, including cement and lime manufacture; 2%, for agricultural uses; and 1%, for special uses and products. Leading States, in order of production, were Texas, Florida, Pennsylvania, Illinois, Georgia, Missouri, Ohio, North Carolina, Virginia, and Tennessee, together accounting for 51% of the total output. Foreign trade in crushed stone was very small throughout the century, compared to the total U.S. production.

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at Sand, Gravel, Surface Stone, Surface Clay, Colloidal Phosphate, or Surface Limestone Mines—30 CFR Parts 46 and 48" became effective. This final rule amends MSHA's existing health and safety training regulations by establishing new training requirements for shell dredging, sand, gravel, surface stone, surface clay, colloidal phosphate, and surface limestone mines. This final rule implements the training requirements of section 115 of the Federal Mine Safety and Health Act of 1997 and provides for effective miner training at the affected mines. At the same time, the final rule allows mine operators the flexibility to tailor their training programs to the specific needs of their miners and operations.

Production

Domestic production data for crushed stone are derived by the U.S. Geological Survey (USGS) from voluntary surveys of U.S. producers. Of the 4,432 crushed stone operations on the mailing list, 3,453 operations with 3,577 quarries owned by 1,367 companies were active. Of the 3,453 active operations, 2,705 operations with 2,791 quarries, representing 78.3% of the total number of active operations, reported to the USGS. Their total production represented 85.3% of the total U.S. crushed stone output. It should be noted that a total of 146 sales yards were active in 2000 in 24 States (table 24). Of the 2,705 reporting operations with 2,791 quarries, 921 operations with 863 quarries and 58 sales yards owned by 139 companies did not report a breakdown by end use. Their production represented 29.6% of the U.S. total and is included in table 13 under "Unspecified, reported" uses. The nonrespondents' production was estimated by using employment data and/or adjusted production reports from prior years. The estimated production from 748 nonresponding operations with 786 quarries owned by 537 companies represented 14.7% of the U.S. total and is included in table 13 under "Unspecified, estimated" uses. Information regarding the number of active operations, active quarries, type of processing plants, and number of sales yards by State is provided in table 24.

A total of 77 underground mines that are included in the total number of active operations produced 48.2 Mt of crushed stone in 2000. Active underground mines were in 15 States. The five leading States, in descending order of tonnage, were Kentucky, Nebraska, Illinois, Iowa, and Indiana. Their production represented 21.7% of the total U.S. crushed stone produced underground.

A total of 933 quarries were either idle or presumed to have been idle in 2000 because no information was available to estimate their production. Since the 1999 survey, 64 operations were closed down. Most of the idle or closed operations were small, temporary quarries, some of them operated by State or local governments. Operations in U.S. territories are not included in the above count.

Of the total 1.56 Gt of crushed stone produced for consumption in the United States in 2000, 1.1 Gt, or 70.4%, was limestone and dolomite; 246 Mt, or 15.8%, was granite; and 114 Mt, or 7.3%, was traprock. The remaining 111 Mt, or 6.5%, was shared, in descending order of quantity, by sandstone and quartzite, miscellaneous stone, marble, calcareous marl, slate, shell, and volcanic cinder and scoria (table 2).

A comparison of the four geographic regions of the United States indicates that, in 2000, the South continued to lead the Nation in the production of crushed stone with 745 Mt, or 47.8% of the total; followed by the Midwest with 444 Mt, or 28.5%; and the Northeast with 207.7 Mt, or 13.3%. About 76% of the total U.S. crushed stone output was produced in the South and the Midwest (table 3).

Of the nine geographic divisions, as shown in figure 1, the South Atlantic led the Nation in the production of crushed stone with 385 Mt, or 24.7% of the U.S. total. It was followed by the East North Central division with 281 Mt, or 18.0%; and the West South Central division with 191 Mt, or 12.2%.

Crushed stone was produced in every State except Delaware. The 10 leading producing States, in descending order of tonnage, were Texas, Pennsylvania, Florida, Georgia, Illinois, Missouri, Ohio, North Carolina, Virginia, and Tennessee. Their combined production represented 52.2% of the national total.

Leading U.S. producing companies, in descending order of tonnage, were Vulcan Materials Co.; Martin Marietta Aggregates; Hanson Building Materials America; Oldcastle, Inc./Materials Group; CSR America, Inc.; Lafarge Corp.; Rogers Group, Inc.; Florida Rock Industries, Inc.; CEMEX, Inc.; and Oglebay Norton Co.

A review of production by size of operation at the national level indicates that in 2000, 846.6 Mt, or 54.3% of total crushed stone, was produced by 477 operations reporting more than 1 million metric tons per year; 384.6 Mt, or 24.6%, was produced by 588 operations reporting between 500,000 and 999,999 metric tons per year (t/yr); and 325.7 Mt, or 20.9%, was produced by operations reporting less than 500,000 t/yr (table 7).

In 2000, consolidation in the aggregates industry continued but at a slower pace. Most of the acquisitions were made by the major producers of aggregates, most of which were publicly owned. These companies tried to expand their base of operations in new areas of the country or acquired operations or companies with significant amounts of reserves. Stricter environmental and permitting regulations make it more difficult to start a new operation than to acquire an existing one. Some of the acquired companies continue to operate as semi-independent organizations but with the benefit of financial and managerial support provided by the larger new owner.

Effective January 1, 2000, Seattle-based Lone Star Northwest changed its name to Glacier Northwest because the company is no longer part of Lone Star Industries, Inc., and did not own the rights to use the Lone Star name (Rock Products, 2000a).

In January, Vulcan Materials Co. of Birmingham, AL, announced the purchase of Garves W. Yates & Sons Co. located in Abilene, TX. The purchase included six quarry sites and four portable aggregates plants. Kiewit Materials Co. of Omaha, NE, acquired Solano Concrete Co., Inc. The company operates a quarry and an aggregates producing plant located in northern California (Rock Products, 2000j).

Also in January, Aggregates Industries, Inc., announced that all its U.S. divisions will now be operating under the Aggregates Industries name. The name change symbolizes the evolution of Aggregates Industries into a unified U.S. company. The divisions affected by the name change include: U.S. Bardon Trimount of Saugus, MA; Bardon Mid-Atlantic of Greenbelt, MD; CAMAS Colorado of Denver, CO; CAMAS Minnesota of Minneapolis, MN; CAMAS Minndak of Fargo, ND; and Bill Smith Sand and Gravel Co. of Otsego, MI. The name change will also be applied to all Aggregates Industries operating businesses in the United Kingdom (Rock Products, 2000b).

In February, Oldcastle Materials Group of Washington, DC, announced the acquisition of The Shelly Co. of Thornville, OH, which operates 3 quarries and 10 sand and gravel pits and supplies markets in southern Ohio and in West Virginia.

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Shelly's aggregates reserves are estimated to be more than 200 Mt (Rock Products, 2000c). Martin Marietta Materials, Inc., of Raleigh, NC, announced the acquisition of the Pennry Stone Co., which operates a limestone quarry north of Columbus, OH, and another limestone quarry at Philippi, WV (Rock Products, 2000h). Aggregates Industries, Inc., of Bethesda, MD, acquired Holst Excavating Co., which operates five limestone quarries and two sand and gravel pits southeast of Minneapolis/St. Paul, MN. Permitted reserves of Holst Excavating Co. are estimated to be more than 200 Mt (Rock Products, 2000a).

On February 14, Graniterock Co. of Watsonville, CA, celebrated its 100th year in business as a family-owned crushed stone producer. In 1993, Graniterock received the Baldridge Award that was created by the U.S. Congress to raise awareness about quality management practices. For the 3 consecutive years between 1997 and 1999, Graniterock Co. was named by Fortune Magazine one of the 100 best companies to work for (Rock Products 2000e).

In June, CSR America of West Palm Beach, FL, announced the acquisition of American Limestone Co. and of Florida Crushed Stone Co. These two acquisitions increased CSR America's production capacity by about 50%, as well as its aggregates reserves (Rock Products, 2000d).

In July, Martin Marietta Materials, Inc., announced that it acquired from A.B. Long Quarries a limestone quarry located near Knoxville, TN, and also signed a long-term contract to process aggregates and assume all responsibility for an operation at Chemical Lime Co.'s New Braunfels, TX, facility. The company also announced that it purchased the Texarkana Asphalt operation, which has a rail-served aggregates distribution yard in Texarkana, TX, and a rail-distribution yard near Wilmington, NC (Rock Products, 2000i). Lafarge Corp. of Hearndon, VA, announced the purchase from Presque Isle Corp. of a limestone quarry located in Presque Isle, MI, about 20 miles (about 34 kilometers) north of Alpena on the shore of Lake Huron, where Lafarge already operates a large quarry and a cement manufacturing plant (Rock Products, 2000f).

In August, Titan Cement S.A. agreed to purchase Tarmac-America, Inc., and subsequently sold all Tarmac America's non-Florida aggregates operations to Vulcan Materials. These operations included four quarries in South Carolina, the Hanover Quarry in Pennsylvania, three quarries and three sand and gravel pits in Virginia, and distribution and marine operations in Maryland and Virginia (Rock Products, 2000k).

U.S. Aggregates announced that it expanded the distribution of aggregates products with a startup of a major sales yard in Memphis, TN, three new yards in Mississippi, and two new yards in the Florida panhandle (Rock Products, 2000l).

In September, Martin Marietta Materials, Inc., announced that under the terms of the October 1998 investment agreement between the two companies, it would buy the remaining part of Meridian Aggregates Co. that it did not already own (Pit & Quarry, 2000b).

In October, CEMEX S.A. de C.V. and Southdown announced that the two companies entered into a definitive merger agreement under which CEMEX would acquire all of the outstanding stock of Southdown. Later that month, it was announced that the merger was completed successfully (Pit & Quarry, 2000a). Global Stone Corp. of Roswell, GA, a wholly owned subsidiary of Oglebay Norton Co., has acquired the assets of the J.M. Huber Corp. limestone processing facility located near Portage, IN. The facility will be known as Global Stone Portage LLC and will use high-quality limestone from their Michigan limestone quarries (Pit & Quarry, 2000c).

After receiving approval votes from most of their member companies, effective September 30, 2000, the National Aggregates Association and the National Stone Association merged to form the National Stone, Sand & Gravel Association. The new association will be the sole organization representing the crushed stone and sand and gravel producing companies at the national level.

Limestone.—The 2000 output of crushed limestone, including some dolomite, increased by 2.6% to 998 Mt valued at $5.0 billion compared with the revised 1999 totals (table 2).

Limestone was produced by 767 companies at 1,965 operations with 1,955 quarries in 47 States. In addition, 38 companies with 50 operations and 52 quarries reported producing limestone and dolomite from the same quarries. Their production of 35.4 Mt is included with the limestone listed in table 2. The limestone totals listed in this chapter, therefore, include an undetermined amount of dolomite in addition to the dolomite reported separately.

The leading producing States, in descending order of tonnage, were Texas, Florida, Missouri, Ohio, and Pennsylvania; these five States accounted for 40% of the total U.S. output (table 8). The leading producers of limestone, in descending order of tonnage, were Martin Marietta Aggregates, Inc.; Vulcan Materials Co; Hanson Building Materials America; Lafarge Corp.; and CSR America.

Dolomite.—Production of dolomite decreased by 1.9% to 101 Mt valued at $533 million compared with the revised 1999 totals (table 2). Crushed dolomite was reportedly produced by 96 companies at 174 operations with 191 quarries in 29 States. An additional undetermined amount of dolomite is included in the total crushed limestone, as explained above.

The leading producing States, in descending order of tonnage, were Illinois, Pennsylvania, Indiana, Ohio, and New York; these five States accounted for 57.1% of the total U.S. output (table 8). The leading producers, in descending order of tonnage, were Oldcastle, Inc./Materials Group; General Dynamics Group; S.E. Johnson Companies, Inc.; Vulcan Materials Co.; and Hanson Building Materials America.

Marble.—Production of crushed marble increased by 6.8% to 11 Mt valued at $64.8 million, compared with the revised figure for 1999 (table 2). Crushed marble was produced by 14 companies with 23 operations and 28 quarries in 11 States (table 9). The leading producers of crushed marble, in descending order of tonnage, were Imerys Marble, Inc.; Florida Rock Industries, Inc.; Pluess Staufer, Inc.; Geogia Marble Stone Corp.; and Vulcan Materials Co.

Calcareous Marl.—Output of marl increased by 3.9% to 3.7 Mt valued at $16.6 million, compared with the 1999 totals (table 2). Marl was produced by seven companies with seven operations and seven quarries in five States (table 9). The leading producers, in descending order of tonnage, were Holderbank/Holman, Inc.; Capitol Aggregates LTD; and Giant Group Ltd.

Shell.—Shell is derived mainly from fossil reefs or oyster shell banks. The output of crushed shell decreased by 1.7% to 1.8 Mt valued at $8.6 million compared with the revised 1999 totals (table 2). Crushed shell was produced by 11 companies with 11 operations in 7 States. The leading producers, in descending order of tonnage, were Caloosa Shell Corp.; Schroeder Manatee, Inc.; and F&W Mines, Inc.

Granite.—The output of crushed granite increased by only 0.8% to 246 Mt valued at $1.6 billion, compared with the revised 1999 totals (table 2). Crushed granite was produced by 139 companies at 375 operations with 369 quarries and 6 sales

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yards in 34 States.

The leading States, in descending order of tonnage, were Georgia, North Carolina, Virginia, South Carolina, and California; these five States accounted for 72.5% of the U.S. output (table 10). The leading producers, in descending order of tonnage, were Vulcan Materials Co., Martin Marietta Aggregates, Hanson Building Materials America, Meridian Aggregates Co., and Florida Rock Industries, Inc.

Traprock.—Production of crushed traprock increased by 1.8% to 114 Mt valued at $724 million, compared with the revised 1999 total (table 2). Traprock was produced by 226 companies at 349 operations with 445 quarries in 24 States.

The leading producing States, in descending order of tonnage, were Oregon, New Jersey, Virginia, Washington, and California; these five States accounted for 61.1% of U.S. output (table 10). Leading producers, in descending order of tonnage, were Oldcastle, Inc./Materials Group; Vulcan Materials Co.; Luck Stone Corp.; Stavola, Inc.; and Eucon Co.

Sandstone and Quartzite.—The combined output of crushed sandstone and quartzite increased by 4.8% to 43.6 Mt, valued at $255 million compared with the revised 1999 totals (table 2). Crushed sandstone was produced by 118 companies at 153 operations with 151 quarries in 24 States, and crushed quartzite was produced by 37 companies at 45 operations with 49 quarries in 17 States.

The leading producing States, in descending order of tonnage of sandstone and quartzite, were Pennsylvania, Arkansas, California, Oklahoma, and South Dakota; their combined production accounted for 56.6% of the U.S. output (table 10). The leading producers of sandstone, in descending order of tonnage, were Lafarge Corp.; Ashland Oil, Inc./APAC, Inc.; and Martin Marietta Aggregates. The leading producers of quartzite were Martin Marietta Aggregates; County Line Quarry, Inc.; and Salem Stone Corp.

Slate.—The output of crushed slate decreased by 18.3% to 2.8 Mt valued at $19.1 million compared with the revised 1999 totals (table 2). Crushed slate was produced by 13 companies at 14 operations with 18 quarries in 10 States.

Most of the crushed slate was produced in North Carolina. The leading producers, in descending order of tonnage, were Martin Marietta Aggregates; McCartney Construction Co., Inc., and NAPA Development Corp., Inc.

Volcanic Cinder and Scoria.—Production of volcanic cinder and scoria decreased by 14.6% to 1.8 Mt valued at $13.2 million compared with the 1999 totals (table 2). Volcanic cinder and scoria were produced by 22 companies from 38 operations with 39 quarries in 12 States.

The leading producing States, in descending order of tonnage, were California, Washington, and Texas (table 11). Leading producers, in descending order of tonnage, were Martin Marietta Aggregates; Peter Kiewit Sons', Inc.; and Bishop Red Rock, Inc.

Miscellaneous Stone.—Output of other kinds of crushed stone decreased by 0.6% to 32.5 Mt valued at $191 million compared with the revised 1999 totals (table 2). Miscellaneous stone was produced by 124 companies at 250 operations with 265 quarries in 28 States.

The leading producing States, in descending order of tonnage, were Pennsylvania, California, and Texas; their combined production accounted for 41.1% of the total U.S. output. Leading producers, in descending order of tonnage, were the U.S. Department of Agriculture's Forest Service; the U.S. Department of the Interior's Bureau of Land Management; U.S. Silica Co.; Aggregates Industries, Inc.; and RMC Group.

Consumption

Crushed stone production reported to the USGS is actually material that was either sold or used by producers. Production that was stockpiled is not included in the reported quantities. The "sold or used" tonnage, therefore, represents the amount of production released for domestic consumption or export in a given year. Because some of the crushed stone producers did not report a breakdown by end use, their total production is included in "Unspecified, reported" use. The estimated production of nonrespondents is included in the "Unspecified, estimated" use.

In 2000, U.S. consumption of crushed stone was 1.56 Gt, a 2.0% increase compared with the revised consumption of 1999. This total is slightly different from the "apparent consumption" of crushed stone that is defined as "U.S. production plus imports minus exports." Of the 1.56 Gt of crushed stone consumed, 691 Mt, or 44.3% of the total, was "Unspecified, reported and estimated" uses. Of the remaining 869 Mt, reported by uses, about 82.3% was used as construction aggregates, mostly for highway and road construction and maintenance; 14.6%, for chemical and metallurgical uses, including cement and lime manufacture; 1.5%, for agricultural uses; and 0.7%, for special uses and products (table 13). To provide a more accurate estimation of the consumption patterns for crushed stone, the "Unspecified" uses are not included in the above percentages. In any use pattern study or marketing analysis, the quantities included in the "Unspecified" uses should be distributed among the reported uses by applying the above percentages to the total of the "Unspecified" uses.

Limestone.—Of the 998 Mt of crushed limestone consumed, 445 Mt, or 44.6%, was in "Unspecified, reported and estimated" uses. Of the remaining 553 Mt of crushed limestone, reported by uses, 75.8% was used as construction aggregates; 21.5%, for chemical and metallurgical applications including cement and lime manufacturing; 2%, for agricultural uses; and 0.8%, for special uses and products (table 14).

Dolomite.—Of the 101 Mt of crushed dolomite consumed, 45.1 Mt, or 44.7%, was in "Unspecified, reported and estimated" uses. Of the remaining 55.9 Mt of crushed dolomite, reported by uses, 91.2% was used as construction aggregates; 3.9%, for chemical and metallurgical applications; and 3.8%, for agricultural uses. An additional undefined amount of dolomite consumed in a variety of uses, mostly construction aggregates, is reported with the limestone (table 14).

Marble.—Of the 11 Mt of crushed marble consumed, 9.2 Mt, or 83.7%, was reported as "Unspecified, reported and estimated" uses. The remaining 1.8 Mt of crushed marble, reported by uses, was used as construction aggregates and for special and miscellaneous uses, including fillers and extenders (table 16).

Calcareous Marl.—Of the 3.7 Mt of crushed calcareous marl consumed, 3.6 Mt, or 97.3%, was used for cement manufacturing.

Shell.—Of the 1.8 Mt of crushed shell consumed, 199,000 metric tons (t), or 11%, was reported as "Unspecified, reported and estimated" uses. Most of the remaining 1.78 Mt was used as construction aggregates.

Granite.—Of the 246 Mt of crushed granite consumed, 99 Mt, or 40.2%, was reported as "Unspecified, reported and estimated" uses. Of the remaining 147 Mt, most was used as construction aggregates (table 17).

Traprock.—Of the 114 Mt of crushed traprock consumed, 55.1 Mt, or 48.3%, was reported as "Unspecified, reported and

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estimated" uses. Of the remaining 58.9 Mt, most was used as construction aggregates (table 17).

Sandstone and Quartzite.—Of the 33 Mt of crushed sandstone consumed, 16 Mt, or 48.5%, was reported as "Unspecified, reported and estimated" uses. Of the remaining 17 Mt of crushed sandstone reported by uses, 15.4 Mt, or 90.6%, was used as construction aggregates (table 18).

Of the 10.6 Mt of crushed quartzite consumed, 3.7 Mt, or 34.9%, was reported as "Unspecified, reported and estimated" uses. Of the remaining 6.9 Mt of crushed quartzite, reported by uses, 5.7 Mt, or 83.3%, was used as construction aggregates (table 18).

Volcanic Cinder and Scoria.—Of the 1.8 Mt of volcanic cinder and scoria consumed, 677,000 t, or 38.5%, was reported as "Unspecified, reported and estimated" uses. Most of the remaining 1.1 Mt of crushed volcanic cinder and scoria was used as construction aggregates (table 19).

Miscellaneous Stone.—Of the 35.3 Mt of miscellaneous crushed stone consumed, 22.2 Mt, or 62.9%, was reported as "Unspecified, reported and estimated" uses. Of the remaining 13.1 Mt reported by uses, 12 Mt, or 91.9%, was used as construction aggregates.

Additional information regarding production and consumption of crushed stone by type of rock and major uses in each State and the State districts may be found in the USGS Minerals Yearbook, volume II, Area Reports: Domestic.

Recycling

As the recycling of most waste materials increases, aggregates producers are recycling more cement concrete and asphalt concrete materials recovered from construction projects to produce concrete aggregates and asphalt aggregates. The annual survey of crushed stone producers now collects information on recycling of cement and asphalt concretes produced by the crushed stone producers only. Information on recycling of these materials by construction or demolition companies is not collected by the USGS.

Asphalt Concrete.—A total of 1.3 Mt of asphalt concrete valued at $7.3 million was recycled by 56 companies in 23 States. This volume represents a 12.4% decrease compared with that of 1999 (tables 20, 21). The leading recycling States, in descending order of tonnage, were California, Wisconsin, and Pennsylvania. The leading recycling companies, in descending order of tonnage produced, were Holmes Construction Co., Inc.; Raisch Products; and Stone Industries, Inc.

Cement Concrete.—A total of 2.3 Mt of cement concrete valued at $13.9 million was recycled by 51 companies in 25 States. This tonnage represents a 34.1% increase compared with that of 1999 (tables 20-22). The leading recycling States, in descending order of tonnage, were Illinois, California, New Jersey, and Florida. The leading companies, in descending order of tonnage produced, were Vulcan Materials Co.; Stone Industries, Inc.; and Dolomite Products.

Prices

Prices in this chapter are average free on board (f.o.b.) plant, usually at the first point of sale or captive use, as reported by the companies. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, inplant transportation, overhead costs, and profit.

The average unit price per ton of crushed stone increased slightly by 0.6% to $5.39 compared with that of 1999. The average unit prices, by kind of stone, increased between 0.7% for limestone and 18.8% for volcanic cinder and scoria and decreased by 0.4% for calcareous marl (table 2).

Transportation

For 722 Mt, or 46.3%, of the 1.56 Gt of crushed stone produced for consumption in 2000, no means of transportation was reported by the producers. Of the remaining 838 Mt of crushed stone, 639 Mt, or 76.3%, was reported as being transported by truck from the processing plant or quarry to the first point of sale or use; 56.7 Mt, or 6.8%, by rail; and 38.6 Mt, or 4.6%, by waterway. About 9% of the specified production was reported as not having been transported and, therefore, is assumed to have been used onsite. Information regarding means of transportation used by the producers to ship crushed stone in each geographic region is provided in table 23.

Foreign Trade

The widespread distribution of domestic deposits of stone suitable for mining as crushed stone and the high cost of transportation limits foreign trade to mostly local transactions across international boundaries. U.S. imports and exports are small, representing less than 1% of domestic consumption. Shipments of crushed stone by water from Canada and especially Mexico, however, continue to increase.

Exports.—Exports of crushed stone decreased by 2.4% to 4 Mt compared with those of 1999, and the value decreased by 3.6% to $29.7 million. About 97% of the exported crushed stone was limestone for cement manufacturing. Canada was the major destination with 99.7% of the total crushed stone (table 25).

Imports.—Imports of crushed stone, including calcium carbonate fines, increased by 5.7% to 13 Mt compared with those of 1999, and the value decreased by 0.9% to $105 million. About 88% of the imported crushed stone was limestone. Imports of natural calcium carbonate fines remained unchanged from the previous year at 1,000 t, while the value increased by 111% to $698,000 (table 26).

Shipments of crushed stone from The Bahamas, Canada, and Mexico into the United States continued in 2000. The imported crushed stone was used mostly as construction aggregates or for cement manufacturing. This trend is expected to continue, and the volume of imports, especially from Mexico, is expected to increase.

Outlook

The demand for crushed stone in 2001 is expected to be about 1.6 Gt, a 2.5% increase compared with 2000. Gradual increases in demand for construction aggregates are anticipated after 2000 as well, based on the expected volume of work on the infrastructure that will be financed by the new Transportation Equity Act for the 21st Century, the Aviation Investment and Reform Act for the 21st Century, and the U.S. economy in general. The projected increases will be influenced by the construction activity in the public and private construction sectors, as well as by the new construction work related to security measures being implemented around the Nation. Crushed stone f.o.b. prices are not expected to increase significantly. The delivered prices of crushed stone, however, are expected to increase, especially in and near metropolitan

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areas, mainly because more aggregates are transported from distant sources.

References Cited

Pit & Quarry, 2000a, CEMEX to acquire Southdown in 2.8 billion transaction: Pit & Quarry, v. 93, no. 5, November, p. 10.

———2000b, Martin Marietta buys rest of Meridian Aggregates: Pit & Quarry, v. 93, no. 4, October, p. 17.

———2000c, Oglebay Norton buys J.M. Huber limestone operation: Pit & Quarry, v. 93, no. 5, November, p. 13.

Rock Products, 2000a, Aggregates Industries acquires four firms: Rock Products, v. 103, no. 3, March, p. 8.

———2000b, Aggregates Industries Consolidates Division Names: Rock Products, v. 103, no. 2, February, p. 21.

———2000c, CRH Oldcastle buys The Shelly Company: Rock Products, v. 103, no. 3, March, p. 8.

———2000d, CSR America embarks on $643 million expansion: Rock Products, v. 103, no. 7, July, p. 7.

———2000e, Graniterock turns 100: Rock Products, v. 103, no. 4, April, p. 26.

———2000f, Lafarge acquires 8 million tpy Michigan quarry: Rock Products, v. 103, no. 8, August, p. 7.

———2000g, Lone Star Northwest now Glacier Northwest: Rock Products, v. 103, no. 2, February, p. 8.

———2000h, Martin Marietta adds 3.3 million capacity: Rock Products, v. 103, no. 3, March, p. 8.

———2000i, Martin Marietta expands in Tennessee, North Carolina, and Texas: Rock Products, v. 103, no. 8, August, p. 7.

———2000j, Vulcan adds to Texas reserves: Rock Products, v. 103, no. 2, February, p. 8.

———2000k, Tarmac America sold to Titan Cement and Vulcan Materials: Rock Products, v. 103, no. 9, September, p. 5.

———2000l, U. S. Aggregates expands distribution in the Southwest: Rock Products, v. 103, no. 9, September, p. 5.

OTHER SOURCES OF INFORMATION

U.S. Geological Survey Publications

Construction Stone. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Crushed Stone and Sand and Gravel. Mineral Industry Surveys, quarterly.

Limestone and Dolomite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Natural Aggregate—Building America's Future. Circular 1110, 1990.

Natural Aggregates of the Conterminous United States. Bulletin 1594, 1988.

Natural Aggregates—Foundation of America's Future. Fact Sheet FS 144-97, 1997.

Stone, Crushed. Ch. in Mineral Commodity Summaries, annual.

Stone, Crushed. Ch. in Minerals Yearbook, annual.

Other

Aggregate Handbook. National Stone Association, 1991.

Aggregates Manager.

Aggregates—Sand, Gravel, & Crushed Rock Aggregates for Construction Purposes. The Geological Society, United Kingdom, 1985.

Concrete Manual, A Water Resources Publication. U.S. Department of the Interior, Bureau of Reclamation, 1975.

Crushed Stone. Mining Engineering, annual review of commodities.

Earth Manual, A Water Resources Publication. U.S. Department of the Interior, Bureau of Reclamation, 1974.

Geology of Nonmetallics. Bates, R.L., and Harben, P.W., Metal Bulletin Inc., 1984.

Handbook of Concrete Aggregates. Dolar-Mantuani, L. Noyes Publications, 1983.

Industrial Minerals.

Stone, Crushed. Ch. in Industrial Minerals and Rocks, Society of Mining, Metallurgy, and Exploration, Inc., 6th ed., Carr, D.D., ed., 1994.

Pit & Quarry.

Rock Products.

Stone, Sand & Gravel Review.

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TABLE 1
SALIENT CRUSHED STONE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
Sold or used by producers: 2/					
Quantity	1,330,000	1,410,000	1,510,000	1,530,000 r/	1,560,000
Value	7,180,000	7,970,000	8,130,000	8,180,000 r/	8,390,000
Exports, value	36,300	42,700	41,500	30,800	29,700
Imports, value 3/	91,800	106,000	116,000	106,000	105,000

r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

3/ Excludes precipitated calcium carbonate.

TABLE 2
CRUSHED STONE SOLD OR USED IN THE UNITED STATES, BY KIND 1/ 2/

	1999				2000			
Kind	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value
Limestone 3/	2,083 r/	973,000 r/	$4,820,000 r/	$4.95 r/	2,007	998,000	$4,980,000	$4.99
Dolomite	189 r/	103,000 r/	531,000 r/	5.13 r/	191	101,000	533,000	5.27
Marble	40 r/	10,300 r/	138,000 r/	13.36 r/	28	11,000	64,800	5.90
Calcareous marl	8	3,580	16,000	4.46	7	3,720	16,600	4.45
Shell	12 r/	1,780 r/	8,250 r/	4.63 r/	11	1,750	8,620	4.93
Granite	402	244,000 r/	1,510,000	6.18 r/	369	246,000	1,580,000	6.41
Traprock	490 r/	112,000 r/	706,000 r/	6.30 r/	445	114,000	724,000	6.35
Sandstone and quartzite 4/	203 r/	41,600 r/	238,000 r/	5.72 r/	200	43,600	255,000	5.85
Slate	19 r/	3,450 r/	22,800 r/	6.60 r/	18	2,820	19,100	6.75
Volcanic cinder and scoria	39 r/	2,060	13,000 r/	6.32 r/	39	1,760	13,200	7.51
Miscellaneous stone	252 r/	32,700 r/	179,000 r/	5.48 r/	265	32,500	191,000	5.88
Total	XX	1,530,000 r/	8,180,000 r/	5.35	XX	1,560,000	8,390,000	5.39

r/ Revised. XX Not applicable.

1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

2/ Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

3/ Includes limestone-dolomite reported with no distinction between the two.

4/ Includes sandstone-quartzite.

TABLE 3
CRUSHED STONE SOLD OR USED IN THE UNITED STATES, BY REGION 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
Region/division	Quantity	Value r/	Quantity	Value
Northeast:				
New England	34,200 r/	224,000	35,700	237,000
Middle Atlantic	162,000 r/	911,000	172,000	994,000
Midwest:				
East North Central	284,000 r/	1,260,000	281,000	1,260,000
West North Central	163,000 r/	799,000	163,000	857,000
South:				
South Atlantic	368,000 r/	2,170,000	385,000	2,280,000
East South Central	174,000 r/	1,060,000	169,000	991,000
West South Central	177,000	755,000	191,000	822,000
West:				
Mountain	56,100 r/	293,000	53,700	285,000
Pacific	110,000 r/	706,000	106,578	659,185
Total	1,530,000 r/	8,180,000	1,560,000	8,390,000

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

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TABLE 4
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY QUARTER AND DIVISION 1/ 2/

Region/division	Quantity 1st quarter (thousand metric tons)	Percentage change 4/	Quantity 2d quarter (thousand metric tons)	Percentage change 4/	Quantity 3d quarter (thousand metric tons)	Percentage change 4/	Quantity 4th quarter (thousand metric tons)	Percentage change 4/	Total 3/ (thousand metric tons)	Value 3/ (thousands)
Northeast:										
New England	3,300	9.3	10,800	3.1	12,200	5.3	9,500	1.4	35,900	$241,000
Middle Atlantic	21,700	6.4	46,900	(2.0)	53,400	(0.9)	40,700	(1.9)	163,000	937,000
Midwest:										
East North Central	38,100	9.2	82,400	1.3	93,100	2.7	75,400	(5.2)	289,000	1,310,000
West North Central	30,300	10.3	47,900	10.2	48,800	(5.3)	33,200	(23.2)	160,000	809,000
South:										
South Atlantic	81,500	6.1	102,000	5.0	100,000	2.4	91,600	(0.9)	375,000	2,260,000
East South Central	35,100	9.6	45,000	(4.7)	47,600	(6.4)	40,200	(10.1)	168,000	1,070,000
West South Central	46,100	8.9	49,500	10.8	52,600	12.6	43,700	3.4	192,000	831,000
West:										
Mountain	12,100	1.8	15,700	5.4	14,700	(10.2)	11,700	(11.6)	54,200	295,000
Pacific 5/	20,500	(0.5)	27,200	1.7	30,400	7.9	27,500	(2.3)	106,000	673,000
Total 3/	289,000	7.1	428,000	3.3	453,000	1.2	374,000	(5.3)	1,560,000 6/	8,550,000 6/

1/ As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2000" chapter of the Mineral Industry Surveys.
2/ Quarterly totals shown are estimates based on a sample survey. Estimated quantities for prior quarters have been recalculated.
3/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.
4/ All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.
5/ Does not include Alaska and Hawaii.
6/ Includes Alaska, Hawaii, and "Other;" see table 6.

TABLE 5
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

	1999			2000		
State	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	49,100 r/	$354,000 r/	$7.22 r/	49,100	$300,000	$6.11
Alaska 3/	1,800 4/ 5/ 6/	9,900 4/ 5/ 6/	5.51	1,400	7,110	5.08
Arizona	8,970 r/	53,900 r/	6.01 r/	8,030	48,200	6.01
Arkansas	30,700	145,000	4.73	28,300	137,000	4.84
California	59,400 r/	384,000 r/	6.46 r/	59,700	373,000	6.26
Colorado	13,200	75,500	5.71	13,000	81,900	6.31
Connecticut	7,170	57,400	8.01	7,740	65,300	8.44
Florida	91,700 r/	466,000 r/	5.08	93,000	495,000	5.33
Georgia	74,200 7/	448,000 7/	6.03	76,500 7/	452,000 7/	5.91
Hawaii	5,870	55,500	9.45	5,770	58,100	10.08
Idaho	4,090 r/	18,500 r/	4.52 r/	3,500	14,800	4.21
Illinois	76,900 r/ 8/	388,000 r/ 8/	5.05	76,000 8/	394,000 8/	5.19
Indiana	58,800 r/	270,000 r/	4.59	55,400	253,000	4.57
Iowa	40,200 r/	203,000 r/	5.05 r/	40,200	209,000	5.20
Kansas	23,700 r/	116,000	4.92	23,300	113,000	4.85
Kentucky	59,800 r/	308,000 r/	5.14 r/	55,600	296,000	5.33
Louisiana 9/	W 8/ 10/	W 8/ 10/	W	W 8/ 10/	W 8/ 10/	W
Maine	3,550 r/	21,200 r/	5.98	3,650	21,100	5.78
Maryland	22,600 r/ 6/ 7/ 11/	121,000 6/ 7/ 11/	5.36 r/	24,500 6/ 7/ 11/	137,000 6/ 7/ 11/	5.61
Massachusetts	11,600	89,900	7.73	13,400	103,000	7.69
Michigan	41,200 r/ 12/ 13/	140,000 r/ 12/ 13/	3.40 r/	42,200 12/ 13/	148,000 12/ 13/	3.52
Minnesota	13,100 r/	62,700 r/	4.80 r/	12,400	68,100	5.50
Mississippi 9/	1,760 12/	15,900 12/	9.00	2,530 12/	23,700 12/	9.37
Missouri	72,600 r/	346,000 r/	4.77 r/	75,500	399,000	5.28
Montana	3,480 r/	13,400 r/	3.86 r/	3,070	12,600	4.12
Nebraska	7,090	44,500	6.28	6,590	42,400	6.43
Nevada	7,090	37,900	5.34	7,640	37,300	4.88
New Hampshire	4,290 8/	19,700 8/	4.59	3,740 8/	15,700 8/	4.19
New Jersey	24,500	160,000	6.54	24,900	170,000	6.82
New Mexico	3,710 r/	22,200	5.98	3,690	22,400	6.07
New York	46,200 r/	266,000 r/	5.75	48,800	304,000	6.22
North Carolina	67,000	459,000	6.85	69,500	478,000	6.88

See footnotes at end of table.

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TABLE 5--Continued
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1999 Quantity (thousand metric tons)	1999 Value (thousands)	1999 Unit value	2000 Quantity (thousand metric tons)	2000 Value (thousands)	2000 Unit value
North Dakota	W 10/ 13/ 14/	W 10/ 13/ 14/	W	W 10/ 13/ 14/	W 10/ 13/ 14/	W
Ohio	73,200	$328,000	$4.47	73,600	$327,000	$4.44
Oklahoma	36,200 r/	145,000	4.00	39,300	168,000	4.28
Oregon	23,300 r/	111,000 r/	4.75 r/	20,800	98,900	4.75
Pennsylvania	91,300 r/	485,000 r/	5.31 r/	97,900	520,000	5.32
Rhode Island	2,070	12,200	5.90	1,860	10,600	5.69
South Carolina	28,600 r/	189,000 r/	6.62 r/	29,400	189,000	6.42
South Dakota	6,020	26,500	4.40	5,460	25,500	4.67
Tennessee	63,100	382,000	6.05	62,100	371,000	5.97
Texas	108,000 r/	447,000 r/	4.13	121,000	496,000	4.10
Utah	8,550 r/	44,400 r/	5.19 r/	8,520	42,100	4.94
Vermont	5,400	22,800	4.23	5,210	21,500	4.12
Virginia	66,400	389,000	5.86	68,800	424,000	6.16
Washington	19,300 r/	146,000	7.55 r/	18,900	122,000	6.43
West Virginia	12,500 r/ 15/	56,500 r/ 15/	4.54 r/	12,100 15/	52,800 15/	4.38
Wisconsin	33,800 r/	135,000 r/	3.98	33,700	137,000	4.07
Wyoming	6,970	27,600	3.96	6,250	26,100	4.18
Other	7,420 r/	59,900 r/	8.07 r/	13,700	74,600	5.43
Total	1,530,000 r/	8,180,000 r/	5.35	1,560,000	8,390,000	5.39

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."
3/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.
4/ Excludes limestone-dolomite.
5/ Excludes slate.
6/ Excludes shell.
7/ Excludes marble.
8/ Excludes sandstone.
9/ A significant amount of sold or used material was shipped in from other States.
10/ Excludes limestone.
11/ Excludes traprock.
12/ Excludes calcareous marl.
13/ Excludes miscellaneous stone.
14/ Excludes volcanic cinder and scoria.
15/ Excludes dolomite.

TABLE 6
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY QUARTER AND STATE 1/ 2/

State	Quantity, 1st quarter (thousand metric tons)	Percentage change 4/	Quantity, 2d quarter (thousand metric tons)	Percentage change 4/	Quantity, 3d quarter (thousand metric tons)	Percentage change 4/	Quantity, 4th quarter (thousand metric tons)	Percentage change 4/	Total 3/ Quantity (thousand metric tons)	Total 3/ Value (thousands)
Alabama	12,100	12.1	13,200	4.1	13,400	(2.4)	11,100	(8.6)	49,800	$370,000
Alaska 5/ 6/	--	--	--	--	--	--	--	--	1,800	10,200
Arizona 7/	--	--	--	--	--	--	--	--	9,160	56,300
Arkansas	6,800	9.0	7,800	(2.3)	9,400	8.5	7,300	(6.6)	31,300	152,000
California	11,800	5.7	15,900	3.9	17,500	4.5	16,600	(2.5)	61,900	409,000
Colorado	2,800	1.3	4,400	15.4	3,700	(1.0)	2,700	(3.5)	13,700	80,100
Connecticut	500	37.0	2,400	(10.5)	2,600	4.0	2,200	36.2	7,700	63,200
Delaware 5/	--	--	--	--	--	--	--	--	--	--
Florida 6/	23,000	1.0	26,200	13.5	24,200	6.1	23,400	(0.7)	96,900	505,000
Georgia 6/	18,100	8.0	20,000	2.4	19,200	(4.7)	17,300	(2.0)	74,700	462,000
Hawaii 5/	--	--	--	--	--	--	--	--	6,000	58,100
Idaho 6/	800	1.9	800	(8.6)	1,000	(29.9)	1,100	(3.1)	3,710	17,100
Illinois	11,200	12.8	21,000	1.0	24,100	1.5	19,300	(13.5)	75,500	391,000
Indiana 6/	9,100	8.1	16,400	(1.8)	19,400	1.5	14,700	(4.0)	59,600	280,000
Iowa	5,900	16.1	12,800	5.8	13,200	(6.2)	8,700	(19.4)	40,700	210,000
Kansas	5,200	0.0	6,400	10.6	6,500	1.2	4,100	(33.5)	22,200	112,000

See footnotes at end of table.

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TABLE 6–Continued
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY QUARTER AND STATE 1/ 2/

State	Quantity, 1st quarter (thousand metric tons)	Percentage change 4/	Quantity, 2d quarter (thousand metric tons)	Percentage change 4/	Quantity, 3d quarter (thousand metric tons)	Percentage change 4/	Quantity, 4th quarter (thousand metric tons)	Percentage change 4/	Total 3/ Quantity (thousand metric tons)	Total 3/ Value (thousands)
Kentucky 6/	10,600	(4.0)	14,800	(10.1)	15,500	(13.5)	13,400	(11.4)	54,200	$286,000
Louisiana 6/ 7/	--	--	--	--	--	--	--	--	--	--
Maine	500	(5.8)	1,300	3.7	1,400	1.0	900	2.8	4,040	24,800
Maryland 6/	4,200	18.7	6,800	12.9	6,900	10.1	6,100	(4.6)	24,000	134,000
Massachusetts 6/	1,300	14.7	3,600	5.2	4,100	8.4	3,200	(3.8)	12,100	96,100
Michigan 6/	3,400	8.7	13,600	4.6	13,500	0.2	11,600	(10.0)	42,100	148,000
Minnesota	900	24.8	4,100	10.3	4,500	(15.1)	2,800	(24.8)	12,200	61,500
Mississippi 6/ 7/	--	--	--	--	--	--	--	--	3,850	35,600
Missouri	16,100	12.0	21,100	18.8	20,700	(4.4)	15,200	(22.5)	73,100	357,000
Montana 7/	--	--	--	--	--	--	--	--	2,810	11,200
Nebraska	1,400	(1.2)	1,900	(3.2)	1,800	(8.5)	1,600	(7.7)	6,710	43,100
Nevada	1,800	57.9	2,300	22.1	2,200	0.2	2,200	16.5	8,480	46,400
New Hampshire 6/	300	(8.1)	1,300	10.6	1,500	3.5	1,200	(7.8)	4,330	20,400
New Jersey	3,600	(0.2)	6,400	(8.3)	7,800	10.4	6,600	(3.9)	24,400	164,000
New Mexico 6/	700	(16.9)	700	(46.6)	700	(30.3)	600	17.7	2,760	16,900
New York	4,100	13.9	13,700	(1.7)	17,400	(3.2)	11,900	6.7	47,200	278,000
North Carolina	14,200	4.2	18,800	2.7	19,100	5.5	17,300	2.3	69,400	487,000
North Dakota 5/	--	--	--	--	--	--	--	--	--	--
Ohio	10,700	7.1	22,700	6.1	25,000	11.3	20,000	3.6	78,400	360,000
Oklahoma 6/	8,200	(10.2)	9,700	4.3	9,900	7.8	7,700	(10.9)	35,600	146,000
Oregon	4,000	6.1	6,800	7.4	7,300	3.6	6,300	(3.5)	24,500	119,000
Pennsylvania	13,800	6.1	26,700	(0.7)	28,500	(2.1)	22,300	(5.0)	91,300	495,000
Rhode Island 5/	--	--	--	--	--	--	--	--	2,070	12,500
South Carolina	6,800	4.2	7,900	2.0	7,100	(9.0)	6,500	(8.5)	28,300	191,000
South Dakota	900	35.2	1,700	(9.1)	2,000	0.1	1,000	(29.7)	5,660	25,500
Tennessee	11,600	18.3	16,300	(7.7)	17,900	(4.3)	15,200	(10.3)	61,000	379,000
Texas	31,500	16.7	32,000	16.7	33,400	15.4	28,900	12.7	126,000	533,000
Utah	1,700	1.9	2,100	0.5	2,400	(12.2)	2,000	(17.4)	8,080	42,600
Vermont 7/	--	--	--	--	--	--	--	--	5,610	24,300
Virginia	12,900	7.2	18,500	(0.7)	19,600	9.6	18,200	1.7	69,100	416,000
Washington	4,800	(22.6)	4,400	(15.7)	5,600	37.9	4,100	1.2	18,900	145,000
West Virginia 6/	2,300	27.6	4,200	9.8	3,900	(8.6)	3,200	0.4	13,500	62,400
Wisconsin	3,300	7.0	8,200	(12.3)	11,000	(9.7)	10,400	4.9	32,900	135,000
Wyoming	1,600	(9.1)	1,900	11.0	1,500	(19.0)	900	(40.0)	6,020	24,400
Other	--	--	--	--	--	--	--	--	8,000	55,800
Total	XX	XX	XX	XX	XX	XX	XX	XX	1,560,000	8,550,000

XX Not applicable. -- Zero.

1/ As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2000" chapter of the Mineral Industry Surveys.

2/ Quarterly totals shown are estimates based on a sample survey. Estimated quantities for prior quarters have been recalculated.

3/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.

4/ All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.

5/ State not included in quarterly survey.

6/ To avoid disclosing proprietary data, some State totals do not include all types of stone produced within the State; portion not shown has been included with "Other."

7/ Owing to the low number of companies, no production estimates by quarter were generated.

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TABLE 7
CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 2000, BY REGION AND SIZE OF OPERATION 1/

Size range (metric tons)	Northeast				Midwest				South			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	46	10.2	385	0.2	167	15.0	1,590	0.4	80	6.9	616	0.1
25,000 to 49,999	18	4.0	630	0.3	98	8.8	3,310	0.7	50	4.3	1,720	0.2
50,000 to 99,999	38	8.4	2,630	1.3	157	14.1	10,700	2.4	99	8.6	6,710	0.9
100,000 to 199,999	65	14.4	9,010	4.4	149	13.3	19,900	4.5	146	12.6	19,800	2.7
200,000 to 299,999	48	10.7	11,000	5.3	107	9.6	23,900	5.4	99	8.6	22,200	3.0
300,000 to 399,999	47	10.4	14,900	7.2	79	7.1	25,200	5.7	95	8.2	30,100	4.0
400,000 to 499,999	33	7.3	13,600	6.6	50	4.5	20,100	4.5	84	7.3	34,500	4.6
500,000 to 599,999	22	4.9	10,900	5.3	52	4.7	26,200	5.9	60	5.2	30,000	4.0
600,000 to 699,999	21	4.7	12,500	6.0	51	4.6	29,700	6.7	56	4.8	33,200	4.5
700,000 to 799,999	16	3.6	10,900	5.3	35	3.1	23,700	5.3	46	4.0	31,300	4.2
800,000 to 899,999	19	4.2	14,900	7.2	30	2.7	23,100	5.2	45	3.9	34,600	4.6
900,000 to 999,999	13	2.9	11,200	5.4	21	1.9	18,300	4.1	44	3.8	38,000	5.1
1,000,000 to 1,499,999	40	8.9	43,800	21.2	59	5.3	63,200	14.2	129	11.1	145,000	19.5
1,500,000 to 1,999,999	13	2.9	20,400	9.9	35	3.1	56,500	12.7	54	4.7	83,900	11.3
2,000,000 to 2,499,999	4	0.9	7,910	3.8	7	0.6	13,500	3.0	23	2.0	47,300	6.3
2,500,000 to 4,999,999	7	1.6	22,700	11.0	13	1.2	41,900	9.4	35	3.0	105,000	14.1
5,000,000 or more	--	--	--	--	7	0.6	43,600	9.8	12	1.0	81,400	10.9
Total	450	100.0	207,000	100.0	1,117	100.0	444,000	100.0	1,157	100.0	745,000	100.0

Size range (metric tons)	West				U.S. total			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	244	33.5	1,390	0.9	537	15.6	3,980	0.3
25,000 to 49,999	82	11.2	2,690	1.7	248	7.2	8,350	0.5
50,000 to 99,999	111	15.2	7,370	4.6	405	11.7	27,400	1.8
100,000 to 199,999	99	13.6	12,700	7.9	459	13.3	61,400	3.9
200,000 to 299,999	44	6.0	9,970	6.2	298	8.6	67,100	4.3
300,000 to 399,999	30	4.1	9,660	6.0	251	7.3	79,900	5.1
400,000 to 499,999	23	3.2	9,460	5.9	190	5.5	77,600	5.0
500,000 to 599,999	22	3.0	10,900	6.8	156	4.5	78,000	5.0
600,000 to 699,999	8	1.1	4,620	2.9	136	3.9	80,000	5.1
700,000 to 799,999	12	1.6	8,110	5.1	109	3.2	74,000	4.7
800,000 to 899,999	5	0.7	3,880	2.4	99	2.9	76,400	4.9
900,000 to 999,999	10	1.4	8,730	5.5	88	2.5	76,200	4.9
1,000,000 to 1,499,999	21	2.9	23,400	14.6	249	7.2	275,000	17.6
1,500,000 to 1,999,999	6	0.8	10,100	6.3	108	3.1	171,000	11.0
2,000,000 to 2,499,999	2	0.3	3,960	2.5	36	1.0	72,600	4.7
2,500,000 to 4,999,999	10	1.4	33,300	20.8	65	1.9	203,000	13.0
5,000,000 or more	--	--	--	--	19	0.6	125,000	8.0
Total	729	100.0	160,000	100.0	3,453	100.0	1,560,000	100.0

-- Zero.

1/ Data are rounded to no more than three significant digits, except "number of operations;" may not add to totals shown.

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TABLE 8
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Alabama	39,500	237,000	W	W
Arizona	4,280	21,700	--	--
Arkansas	8,660	37,800	W	W
California	29,200	149,000	256	2,060
Colorado	3,050	17,600	W	W
Connecticut	W	W	W	W
Florida	89,200 2/	472,000 2/	2,280	15,900
Georgia	8,890	54,200	W	W
Hawaii	248	2,150	--	--
Idaho	607	1,920	--	--
Illinois	58,600 2/	307,000 2/	17,400	87,600
Indiana	44,300 2/	205,000 2/	11,000	47,800
Iowa	40,100 2/	209,000 2/	W	W
Kansas	22,600 2/	110,000 2/	--	--
Kentucky	54,000	291,000	W	W
Louisiana 3/	W	W	--	--
Maine	1,300	7,260	--	--
Maryland	18,400 2/	93,400 2/	--	--
Massachusetts	W	W	W	W
Michigan	34,400 2/	118,000 2/	7,770	30,300
Minnesota	6,400	30,300	W	W
Mississippi 3/	2,530	23,700	--	--
Missouri	70,200 2/	337,000 2/	3,880	18,700
Montana	2,300	9,650	--	--
Nebraska	6,590	42,400	--	--
Nevada	4,800	18,900	W	W
New Jersey	569	7,210	--	--
New Mexico	2,200	9,320	--	--
New York	29,500 2/	165,000 2/	8,380	60,800
North Carolina	W	W	325	2,170
North Dakota	W	W	--	--
Ohio	64,000 2/	284,000 2/	9,130	40,300
Oklahoma	31,200	134,000	W	W
Oregon	W	W	--	--
Pennsylvania	60,300 2/	319,000 2/	11,800	63,800
Rhode Island	W	W	--	--
South Carolina	W	W	--	--
South Dakota	2,980	12,600	--	--
Tennessee	57,300	341,000	W	W
Texas	115,000 2/	468,000 2/	W	W
Utah	4,840 2/	23,600 2/	W	W
Vermont	2,210	8,780	W	W
Virginia	21,300 2/	118,000 2/	3,850	23,300
Washington	2,040 2/	29,300 2/	W	W
West Virginia	10,900	47,000	W	W
Wisconsin	27,000 2/	111,000 2/	1,780	7,300
Wyoming	2,130 2/	9,840 2/	--	--
Other	14,300 2/	98,700 2/	23,400	133,000
Total	998,000	4,980,000	101,000	533,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes limestone-dolomite reported with no distinction between the two kinds of stone.
3/ A significant amount of sold or used material was shipped in from other States.

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TABLE 9
CRUSHED CALCAREOUS MARL AND MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Calcareous marl		Marble	
	Quantity	Value	Quantity	Value
Alabama	--	--	W	W
California	--	--	18	127
Pennsylvania	--	--	W	W
Oregon	100	338	--	--
Vermont	--	--	W	W
Other	3,620 2/	16,200 2/	11,000 3/	64,600 3/
Total	3,720	16,600	11,000	64,800

W Withheld to avoid disclosing company propreitary data, included in "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes data for Michigan, Mississippi, South Carolina, and Texas.
3/ Includes data for Arizona, Georgia, Maryland, New York, South Carolina, Texas, and Wyoming.

TABLE 10
CRUSHED GRANITE, TRAPROCK, AND SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Granite		Traprock		Sandstone and quatzite 2/	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	--	--	2,310	15,500
Alaska 3/	W	W	W	W	--	--
Arizona	1,870	14,400	208	2,400	W	W
Arkansas	10,200	53,400	--	--	7,270	35,100
California	10,400	75,100	10,800	79,000	3,400	29,300
Colorado	4,450	33,100	W	W	W	W
Connecticut	324	2,460	5,810	41,400	--	--
Georgia	66,100	388,000	--	--	W	W
Hawaii	--	--	5,010	51,300	--	--
Idaho	240	975	1,990	8,960	W	W
Illinois	--	--	--	--	W	W
Kansas	--	--	--	--	W	W
Louisiana 4/	--	--	--	--	W	W
Maine	1,320	7,150	46	409	W	W
Maryland	4,070	28,600	W	W	W	W
Massachusetts	5,210	37,500	6,700	48,600	--	--
Michigan	--	--	--	--	12	195
Minnesota	W	W	--	--	W	W
Missouri	W	W	W	W	--	--
Montana	161	620	W	W	W	W
Nevada	W	W	93	419	--	--
New Hampshire	1,820	7,200	W	W	W	W
New Jersey	10,000	59,700	14,200	102,000	--	--
New Mexico	W	W	--	--	W	W
New York	W	W	W	W	1,550	10,700
North Carolina	53,200	365,000	5,330	39,600	W	W
Ohio	--	--	--	--	W	W
Oklahoma	W	W	--	--	2,510	14,400
Oregon	W	W	17,500	82,800	--	--
Pennsylvania	4,700	24,300	4,630	23,400	9,130	49,600
Rhode Island	1,370	7,730	W	W	--	--
South Carolina	22,000	147,000	--	--	--	--
South Dakota	W	W	--	--	2,350	12,400
Tennessee	W	W	--	--	W	W
Texas	W	W	W	W	1,080	6,110
Utah	--	--	--	--	767	5,680
Vermont	268	1,930	--	--	W	W
Virginia	26,700	183,000	13,900	85,000	1,950	8,590
Washington	2,000	10,900	13,200	71,000	W	W
West Virginia	--	--	--	--	1,210	5,810

See footnotes at end of table.

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TABLE 10--Continued
CRUSHED GRANITE, TRAPROCK, AND SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Granite		Traprock		Sandstone and quatzite 2/	
	Quantity	Value	Quantity	Value	Quantity	Value
Wisconsin	1,800	6,800	W	W	W	W
Wyoming	W	W	--	--	--	--
Other	18,100	123,000	14,500	87,300	10,100	61,700
Total	246,000	1,580,000	114,000	724,000	43,600	255,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes sandstone-quartzite.
3/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.
4/ A significant amount of sold or used material was shipped in from other States.

TABLE 11
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Volcanic cinder and scoria		Miscellaneous stone 2/	
	Quantity	Value	Quantity	Value
Alabama	--	--	W	W
Alaska 3/	--	--	W	W
Arizona	113	464	1,530	8,990
Arkansas	--	--	611	3,140
California	185	2,000	5,400	36,100
Colorado	W	W	2,080	12,800
Connecticut	--	--	1	5
Hawaii	--	--	W	W
Idaho	--	--	156	773
Indiana	--	--	W	W
Maine	--	--	488	3,240
Maryland	--	--	1,840	14,300
Massachusetts	--	--	446	3,540
Michigan	--	--	W	W
Montana	--	--	59	229
Nevada	W	W	W	W
New Jersey	--	--	W	W
New Mexico	W	W	637	3,830
New York	--	--	898	5,050
North Carolina	W	W	3,800	23,800
North Dakota	W	W	W	W
Oklahoma	--	--	W	W
Oregon	W	W	1,680	7,730
Pennsylvania	--	--	6,700	35,800
Texas	W	W	2,400	10,400
Utah	W	W	527	4,110
Vermont	--	--	W	W
Virginia	--	--	1,050	6,250
Washington	165	980	576	2,520
Wyoming	W	W	788	3,040
Other	1,300	9,770	3,620	24,100
Total	1,760	13,200	35,300	210,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes slate.
3/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 12
KIND OF CRUSHED STONE PRODUCED AND/OR DISTRIBUTED IN THE UNITED STATES IN 2000, BY STATE

State	Lime-stone	Dolo-mite	Marble	Calcareous marl	Shell	Granite	Trap-rock	Sand-stone	Quartzite	Slate	Volcanic cinder and scoria	Miscella-neous
Alabama	X	X	X			X		X		X		X
Alaska 1/						X	X					X
Arizona	X		X			X	X	X			X	X
Arkansas	X	X				X		X	X			X
California	X	X	X		X	X	X	X	X	X	X	X
Colorado	X	X				X	X	X	X		X	X
Connecticut	X	X				X	X					X
Florida	X	X			X							
Georgia	X	X	X			X			X			X
Hawaii	X						X					X
Idaho	X				X	X	X		X			X
Illinois	X	X						X				X
Indiana	X	X								X		
Iowa	X	X										
Kansas	X							X	X			X
Kentucky	X	X										
Louisiana	X							X				X
Maine	X					X	X		X	X		X
Maryland	X		X		X	X	X	X				X
Massachusetts	X	X				X	X					X
Michigan	X	X		X				X				X
Minnesota	X	X				X			X			
Mississippi	X			X								
Missouri	X	X				X	X					
Montana	X					X	X	X	X			X
Nebraska	X											
Nevada	X	X				X	X				X	X
New Hampshire						X	X	X				
New Jersey	X					X	X					X
New Mexico	X					X		X			X	X
New York	X	X	X			X	X	X		X		X
North Carolina	X	X				X	X		X	X	X	X
North Dakota	X										X	X
Ohio	X	X						X				
Oklahoma	X	X			X	X		X				X
Oregon	X			X	X	X	X				X	X
Pennsylvania	X	X	X			X	X	X	X	X		X
Rhode Island	X					X	X					
South Carolina	X		X	X		X						
South Dakota	X					X			X			
Tennessee	X	X				X		X				
Texas	X	X	X	X	X	X	X	X	X		X	X
Utah	X	X						X	X		X	X
Vermont	X	X	X			X			X	X		
Virginia	X	X				X	X	X	X	X		X
Washington	X	X				X	X	X		X	X	X
West Virginia	X	X						X				
Wisconsin	X	X				X	X	X	X			
Wyoming	X		X			X					X	X

1/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 13
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Construction:			
Coarse aggregate (+1½ inch):			
Macadam	8,130	$46,200	$5.68
Riprap and jetty stone	17,100	125,000	7.33
Filter stone	6,140	41,100	6.70
Other coarse aggregate	11,100	61,500	5.51
Coarse aggregate, graded:			
Concrete aggregate, coarse	93,000	612,000	6.58
Bituminous aggregate, coarse	75,000	518,000	6.90
Bituminous surface-treatment aggregate	15,600	107,000	6.87
Railroad ballast	10,800	59,500	5.50
Other graded coarse agggregate	79,600	482,000	6.06
Fine aggregate (-3/8 inch):			
Stone sand, concrete	21,900	134,000	6.10
Stone sand, bituminous mix or seal	16,200	97,700	6.01
Screening, undesignated	22,100	117,000	5.28
Other fine aggregate	31,300	159,000	5.08
Coarse and fine aggregates:			
Graded road base or subbase	136,000	689,000	5.06
Unpaved road surfacing	22,500	109,000	4.86
Terrazzo and exposed aggregate	1,660	16,400	9.89
Crusher run or fill or waste	35,100	171,000	4.86
Roofing granules	5,730	75,800	13.22
Other coarse and fine aggregates	92,800	461,000	4.97
Other construction materials 2/	13,400	81,100	6.06
Agricultural:			
Agricultural limestone	10,900	61,900	5.68
Poultry grit and mineral food	1,380	11,600	8.46
Other agricultural uses	1,010	8,450	8.35
Chemical and metallurgical:			
Cement manufacture	102,000	408,000	4.01
Lime manufacture	18,300	110,000	6.01
Dead-burned dolomite manufacture	658	3,200	4.87
Flux stone	4,010	19,600	4.87
Chemical stone	W	W	4.89
Glass manufacture	W	W	18.74
Sulfur oxide removal	2,250	10,200	4.54
Special:			
Mine dusting or acid water treatment	211	3,960	18.79
Asphalt fillers or extenders	1,450	13,200	9.10
Whiting or whiting substitute	1,030	22,200	21.51
Other fillers or extenders	2,990	43,700	14.63
Other miscellaneous uses:			
Abrasives	W	W	3.59
Flour (slate)	W	W	49.60
Sugar refining	W	W	12.97
Other specified uses not listed	2,250	12,600	5.60
Unspecified: 3/			
Reported	461,000	2,340,000	5.08
Estimated	230,000	1,100,000	4.94
Total	1,560,000	8,390,000	5.39

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits, except unit values; may not add to totals shown.
2/ Includes acid neutralization, building products, drain fields, lightweight aggregate (slate), pipe bedding, and refractory stone.
3/ Reported and estimated production without a breakdown by end use.

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TABLE 14
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE

(Thousand metric tons and thousand dollars)

Use	Limestone 2/		Dolomite	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	3,080	17,500	366	2,200
Riprap and jetty stone	10,400	64,000	755	5,300
Filter stone	3,480	19,900	139	882
Other coarse aggregate	7,200	39,700	238	1,600
Coarse aggregate, graded:				
Concrete aggregate, coarse	54,300	321,000	7,790	51,800
Bituminous aggregate, coarse	44,100	284,000	4,960	32,100
Bituminous surface-treatment aggregate	7,890	45,700	2,060	13,500
Railroad ballast	1,420	7,530	423	2,340
Other graded coarse aggregate	54,400	314,000	2,120	14,500
Fine aggregate (-3/8 inch):				
Stone sand, concrete	12,900	71,000	1,700	12,400
Stone sand, bituminous mix or seal	8,690	50,400	951	6,070
Screening, undesignated	12,000	60,700	1,270	7,360
Other fine aggregate	21,800	106,000	995	5,960
Coarse and fine aggregates:				
Graded road base or subbase	84,900	399,000	11,500	58,800
Unpaved road surfacing	16,200	80,000	2,690	11,300
Terrazzo and exposed aggregate	732	4,670	31	220
Crusher run or fill or waste	19,500	84,600	1,300	6,670
Other coarse and fine aggregates	49,900	239,000	11,200	49,400
Roofing granules	352	2,750	W	W
Other construction materials 3/	6,150	33,500	474	2,910
Agricultural:				
Agricultural limestone	8,790	48,100	2,110	13,800
Poultry grit and mineral food	1,330	11,000	--	--
Other agricultural uses	896	7,580	34	337
Chemical and metallurgical:				
Cement manufacture	96,900	383,000	55	189
Lime manufacture	17,300	106,000	960	3,600
Dead-burned dolomite manufacture	284	1,350	W	W
Flux stone	2,300	11,600	1,180	4,760
Chemical stone	W	W	--	--
Glass manufacture	W	W	--	--
Sulfur oxide removal	2,250	10,200	--	--
Special:				
Mine dusting or acid water treatment	211	3,960	--	--
Asphalt fillers or extenders	1,240	11,500	W	W
Whiting or whiting substitute	662	12,100	W	W
Other fillers or extenders	2,380	37,800	129	2,380
Other miscellaneous uses:				
Refractory stone (including ganister)	W	W	--	--
Acid neutralization	W	W	--	--
Sugar refining	216	2,800	--	--
Other specified uses not listed	1,540	7,730	46	407
Unspecified: 4/				
Reported	285,000	1,340,000	36,200	170,000
Estimated	160,000	740,000	8,900	39,000
Total	998,000	4,980,000	101,000	533,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes a minor amount of limestone-dolomite reported without a distinction between the two.

3/ Includes drain fields and pipe bedding.

4/ Reported and estimated production without a breakdown by end use.

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TABLE 15
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN 2000, BY STATE AND USE 1/

(Thousand metric tons and thousand dollars)

State	Concrete aggregate		Bituminus aggregate		Roadstone and coverings		Riprap and railroad ballast		Other construction uses	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	3,480	18,400	8,220	52,600	1,540	9,310	W	W	5,660	36,000
Arizona	W	W	--	--	--	--	--	--	--	--
Arkansas	520	2,440	1,280	7,470	1,370	6,100	135	676	787	3,500
California	1,110	6,120	359	1,770	432	2,440	W	W	506	2,270
Colorado	--	--	W	W	W	W	W	W	W	W
Connecticut	--	--	W	W	--	--	--	--	--	--
Florida	26,300	157,000	19,000	128,000	11,100	45,400	350	2,750	10,700	49,300
Georgia	1,520	9,210	1,980	13,700	967	5,150	50	535	959	5,440
Hawaii	W	W	W	W	W	W	--	--	W	W
Idaho	--	--	--	--	--	--	--	--	--	--
Illinois	7,190	45,300	6,710	44,600	14,800	71,500	674	5,500	3,840	18,100
Indiana	4,330	21,500	6,470	32,000	5,600	27,200	W	W	5,800	25,300
Iowa	1,070	8,390	582	4,290	5,050	31,900	108	827	922	6,340
Kansas	892	4,740	1,580	8,130	1,330	6,330	135	1,410	2,000	10,100
Kentucky	4,560	24,400	10,600	59,700	7,600	38,100	W	3,060	5,050	24,300
Louisiana 2/	W	W	W	W	W	W	--	--	W	W
Maine	146	653	--	--	--	--	--	--	--	--
Maryland	W	W	2,820	16,800	265	1,640	W	W	2,940	12,900
Massachusetts	--	--	--	--	--	--	--	--	W	W
Michigan	3,340	13,700	1,400	6,790	1,650	7,500	W	W	1,410	5,730
Minnesota	148	841	958	6,900	1,300	6,550	55	616	1,250	6,520
Mississippi 2/	W	W	W	W	W	W	--	--	W	W
Missouri	3,670	20,700	5,860	35,500	8,830	41,700	2,940	13,900	5,370	25,100
Montana	6	23	--	--	W	W	6	44	16	58
Nebraska	955	7,990	650	5,050	334	2,720	183	1,820	613	4,530
Nevada	W	W	--	--	W	W	--	--	--	--
New Jersey	78	800	69	1,140	36	200	--	--	311	2,800
New Mexico	W	W	W	W	95	416	4	20	194	1,040
New York	4,630	34,600	6,900	49,800	4,310	29,200	197	1,420	5,420	29,000
North Carolina	210	1,720	W	W	82	522	W	W	306	2,180
North Dakota	--	--	W	W	W	W	W	W	--	--
Ohio	4,340	20,900	5,370	27,900	15,000	64,000	2,750	14,500	14,400	58,600
Oklahoma	1,690	9,440	8,290	35,700	2,000	9,850	W	W	7,560	31,700
Oregon	--	--	--	--	W	W	W	W	W	W
Pennsylvania	4,350	26,500	9,760	60,600	6,470	35,100	W	W	8,190	40,900
Rhode Island	--	--	--	--	--	--	--	--	W	W
South Carolina	--	--	--	--	W	W	--	--	--	--
South Dakota	W	W	W	W	W	W	W	W	W	W
Tennessee	4,740	30,000	14,800	98,500	12,800	71,900	1,350	8,380	6,850	39,000
Texas	14,200	72,000	7,290	39,800	12,100	44,700	W	W	5,220	18,600
Utah	W	W	64	242	669	2,260	83	471	104	357
Vermont	W	W	W	W	W	W	W	W	W	W
Virginia	2,040	12,800	2,290	13,700	1,570	9,660	216	1,510	3,870	17,200
Washington	--	--	W	W	W	W	W	W	W	W
West Virginia	477	1,880	770	3,160	673	3,070	22	171	2,490	9,330
Wisconsin	1,990	9,200	527	2,920	6,320	25,600	W	W	2,290	10,900
Wyoming	W	W	W	W	W	W	W	W	W	W
Total	98,100	561,000	125,000	757,000	124,000	600,000	12,600	77,100	105,000	497,000
Total withheld	1,390	7,270	1,880	15,700	1,790	9,630	346	2,080	1,490	15,700
Grand total	99,400	568,000	126,000	773,000	126,000	610,000	13,000	79,200	107,000	513,000

See footnotes at end of table.

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TABLE 15--Continued
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN 2000, BY STATE AND USE 1/

(Thousand metric tons and thousand dollars)

State	Cement manufacture		Agricultural uses		Lime manufacture		Other uses		Total by State	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	1,810	5,180	266	1,510	W	W	19,500	123,000	(3/)	(3/)
Arizona	W	W	--	--	W	W	331	1,770	4,280	21,700
Arkansas	W	W	251	1,120	W	W	4,320	20,200	(3/)	(3/)
California	14,600	65,900	156	2,240	W	W	12,200	70,000	29,400	151,000
Colorado	1,480	5,780	W	W	--	--	1,300	6,740	(3/)	(3/)
Connecticut	--	--	W	W	--	--	1,490	20,000	(3/)	(3/)
Florida	5,700	20,400	681	4,050	--	--	17,700	81,100	91,500 4/	488,000 4/
Georgia	W	W	W	W	--	--	2,770	18,300	(3/)	(3/)
Hawaii	--	--	W	W	--	--	W	W	248	2,150
Idaho	W	W	51	174	--	--	180	711	607	1,920
Illinois	2,430	19,200	1,630	6,440	W	W	38,300	182,000	76,000 4/	394,000 4/
Indiana	3,580	14,600	1,330	6,490	W	W	27,300	120,000	55,300 4/	253,000 4/
Iowa	W	W	997	3,950	W	W	28,800	144,000	(3/) 4/	(3/) 4/
Kansas	2,720	11,100	101	500	3	18	13,900	68,100	22,600 4/	110,000 4/
Kentucky	W	5,610	723	3,100	3,960	34,500	21,000	103,000	(3/)	(3/)
Louisiana 2/	--	--	--	--	--	--	W	W	(3/)	(3/)
Maine	W	W	--	--	W	W	598	3,540	1,300	7,260
Maryland	2,560	8,360	--	--	--	--	9,650	52,400	18,400 4/	93,400 4/
Massachusetts	--	--	W	W	W	W	258	6,510	(3/)	(2/)
Michigan	6,490	13,400	71	592	W	W	26,400	93,600	42,200 4/	148,000 4/
Minnesota	--	--	313	1,630	--	--	5,740	27,700	(2/)	(3/)
Mississippi 2/	W	W	W	W	--	--	394	3,470	2,530	23,700
Missouri	4,360	14,300	993	4,250	1,600	7,290	40,500	193,000	74,100 4/	355,000 4/
Montana	W	W	8	142	W	W	1,200	4,360	2,300	9,650
Nebraska	W	W	333	3,410	--	--	W	W	6,590	42,400
Nevada	W	W	W	W	W	W	3,070	12,000	(3/)	(3/)
New Jersey	--	--	64	2,130	--	--	10	141	569	7,210
New Mexico	--	--	W	W	--	--	1,400	6,010	2,200	9,320
New York	4,440	15,700	155	1,400	--	--	11,800	65,000	37,900 4/	226,000 4/
North Carolina	--	--	9	52	--	--	W	W	(3/)	(3/)
North Dakota	--	--	--	--	--	--	W	W	(3/)	(3/)
Ohio	1,460	6,150	649	2,880	W	W	28,800	128,000	73,100 4/	324,000 4/
Oklahoma	W	W	161	559	--	--	10,900	40,800	(3/)	(3/)
Oregon	1,020	3,740	--	--	--	--	216	2,800	(3/)	(3/)
Pennsylvania	6,960	33,100	563	5,520	W	W	33,200	166,000	72,100 4/	383,000 4/
Rhode Island	--	--	W	W	--	--	W	W	(3/)	(3/)
South Carolina	W	W	--	--	--	--	W	W	(3/)	(3/)
South Dakota	W	W	--	--	W	W	W	W	2,980	12,600
Tennessee	W	W	1,590	6,340	W	W	17,700	101,000	(3/)	(3/)
Texas	12,000	43,600	190	1,680	W	W	63,700	246,000	(3/) 4/	(3/) 4/
Utah	W	W	53	875	W	W	2,960	11,700	(3/) 4/	(3/) 4/
Vermont	--	--	--	--	--	--	2,070	8,440	(3/)	(3/)
Virginia	W	W	1,160	10,200	1,390	9,280	11,100	61,700	25,200 4/	141,000 4/
Washington	796	4,740	W	W	W	W	1,520	26,300	(3/) 4/	(3/) 4/
West Virginia	W	W	W	W	--	--	7,430	33,200	(3/)	(3/)
Wisconsin	--	--	286	2,450	W	W	17,100	66,000	28,800 4/	118,000 4/
Wyoming	W	W	--	--	--	--	W	W	2,130 4/	9,840 4/
Total	72,400	291,000	12,800	74,100	6,950	51,100	487,000	2,320,000	XX	XX
Total withheld	23,400	92,700	354	6,720	12,000	62,000	12,300	76,100	XX	XX
Grand total	95,800	384,000	13,200	80,800	18,900	113,000	499,000	2,400,000	1,100,000	5,520,000

W Withheld to avoid disclosing company proprietary data; included in "Total withheld" and "Total by State." XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ A significant amount of sold or used material was shipped in from other States.

3/ Withheld to avoid disclosing company proprietary data; included in "Grand total."

4/ Includes limestone-dolomite reported with no distinction between the two kinds of stone.

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TABLE 16
CRUSHED MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE

(Thousand metric tons and thousand dollars)

Use	Quantity	Value
Construction:		
Coarse aggregate (+1½ inch):		
Macadam	W	W
Riprap and jetty stone	W	W
Filter stone	W	W
Other coarse aggregate	3	22
Coarse aggregate, graded:		
Concrete aggregate, coarse	(2/)	(2/)
Bituminous aggregate, coarse	(2/)	(2/)
Bituminous surface-treatment aggregate	(2/)	(2/)
Other graded coarse aggregate	554	4,720
Fine aggregate (-3/8 inch):		
Screening, undesignated	(3/)	(3/)
Other fine aggregate	31	201
Coarse and fine aggregates:		
Graded road base or subbase	(4/)	(4/)
Terrazzo and exposed aggregate	(4/)	(4/)
Crusher run (select material or fill)	(4/)	(4/)
Other coarse and fine aggregates	456	2,510
Special, other fillers or extenders	W	W
Unspecified: 5/		
Reported	4,110	22,800
Estimated	5,100	29,000
Total	11,000	64,800

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Included with "Other graded coarse aggregate."
3/ Included with "Other fine aggregate."
4/ Included with "Other coarse and fine aggregates."
5/ Reported and estimated production without a breakdown by end use.

TABLE 17
CRUSHED GRANITE AND TRAPROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Granite		Traprock	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	3,830	21,500	489	2,650
Riprap and jetty stone	2,370	24,800	1,500	13,500
Filter stone	1,300	12,300	824	5,400
Other coarse aggregate	1,880	9,190	852	5,100
Coarse aggregate, graded:				
Concrete aggregate, coarse	21,400	158,000	6,290	54,000
Bituminous aggregate, coarse	15,600	124,000	7,280	56,600
Bituminous surface-treatment aggregate	2,760	24,400	1,720	13,600
Railroad ballast	6,590	35,300	1,690	9,170
Other graded coarse aggregate	17,600	109,000	1,650	15,400
Fine aggregate (-3/8 inch):				
Stone sand, concrete	4,710	29,300	1,260	12,500
Stone sand, bituminous mix or seal	3,690	23,800	1,360	8,910
Screening, undesignated	5,480	28,600	1,960	13,000
Other fine aggregate	5,490	26,300	681	5,960
Coarse and fine aggregates:				
Graded road base or subbase	20,000	122,000	12,700	74,100
Unpaved road surfacing	712	4,190	1,840	8,960
Terrazzo and exposed aggregate	486	6,470	W	W
Crusher run or fill or waste	10,300	60,700	2,590	12,600
Other coarse and fine aggregates	17,700	94,300	10,000	55,600
Roofing granules	3,620	58,500	620	9,520

See footnotes at end of table.

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TABLE 17--Continued
CRUSHED GRANITE AND TRAPROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Granite		Traprock	
	Quantity	Value	Quantity	Value
Construction--Continued:				
Other construction materials	1,590	10,400	3,120	22,200
Agricultural, other agricultural uses	W	W	W	W
Chemical and metallurgical, lime manufacture	W	W	--	--
Special:				
Asphalt fillers or extenders	W	W	W	W
Other fillers or extenders	W	W	--	--
Other miscellaneous uses and specified uses not listed	55	329	5	90
Unspecified: 2/				
Reported	79,000	488,000	29,100	175,000
Estimated	20,000	110,000	26,000	150,000
Total	246,000	1,580,000	114,000	724,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Reported and esitmated production without a breakdown by end use.

TABLE 18
CRUSHED SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	Sandstone		Quartzite	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	W	W	--	--
Riprap and jetty stone	801	8,550	67	502
Filter stone	95	666	68	353
Other coarse aggregate	121	875	147	633
Coarse aggregate, graded:				
Concrete aggregate, coarse	1,310	8,740	275	1,780
Bituminous aggregate, coarse	1,900	12,700	405	2,980
Bituminous surface-treatment aggregate	609	6,520	110	1,110
Railroad ballast	54	344	389	2,650
Other graded coarse aggregate	1,210	10,200	798	4,880
Fine aggregate (-3/8 inch):				
Stone sand, concrete	991	6,670	W	W
Stone sand, bituminous mix or seal	742	4,230	213	1,570
Screening, undesignated	778	4,300	362	1,940
Other fine aggregate	1,050	6,660	935	5,320
Coarse and fine aggregates:				
Graded road base or subbase	2,780	14,800	558	3,310
Unpaved road surfaces	383	2,060	W	W
Terrazzo and exposed aggregate	W	W	W	W
Crusher run or fill or waste	548	2,490	273	1,450
Other coarse and fine aggregates	1,830	10,300	772	2,900
Roofing granules	W	W	W	W
Other construction materials 3/	198	3,200	376	1,720
Agricultural, poultry grit and mineral food	--	--	W	W
Chemical and metallurgical:				
Cement manufacture	345	1,870	251	1,980
Flux stone	W	W	W	W
Special:				
Asphalt fillers or extenders	W	W	--	--
Other fillers or extenders	W	W	--	--
Other miscellaneous uses:				
Refractory stone (including ganister)	W	W	--	--
Abvasives	W	W	--	--
Other uses not listed	W	W	W	W

See footnotes at end of table.

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TABLE 18--Continued
CRUSHED SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	Sandstone		Quartzite	
	Quantity	Value	Quantity	Value
Unspecified: 4/				
Reported	10,300	55,300	2,820	12,500
Estimated	5,700	31,000	883	4,500
Total	33,000	197,000	10,600	58,200

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Includes sandstone-quartzite.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes building products.
4/ Reported and estimated production without a breakdown by end use.

TABLE 19
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Volcanic cinder and scoria		Miscellaneous stone 2/	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	--	--	W	W
Riprap and jetty stone	8	42	1,160	8,190
Filter stone	W	W	153	876
Other coarse aggregate	--	--	679	4,150
Coarse aggregate, graded:				
Concrete aggregate, coarse	W	W	1,500	15,800
Bituminous aggregate, coarse	--	--	517	3,810
Bituminous surface-treatment aggregate	--	--	407	1,920
Railroad ballast	--	--	229	2,180
Other graded coarse aggregate	43	169	1,690	12,600
Fine aggregate (-3/8 inch):				
Stone sand, concrete	--	--	266	1,440
Stone sand, bituminous mix or seal	--	--	595	2,700
Screening, undesignated	72	280	137	583
Other fine aggregate	9	104	342	2,440
Coarse and fine aggregates:				
Graded road base or subbase	239	1,220	1,680	7,300
Unpaved road surfacing	6	26	691	2,780
Terrazzo and exposed aggregate	258	4,020	W	W
Crusher run or fill or waste	37	137	414	1,610
Other coarse and fine aggregates	--	--	1,390	9,350
Roofing granules	W	W	W	W
Other construction materials	107	1,060	185	1,130
Agricultural, other agricultural uses	--	--	W	W
Chemical and metallurgical, cement manufacture	--	--	715	4,570
Other miscellaneous uses:				
Light weight aggregate (slate)	--	--	W	W
Flour (slate)	--	--	W	W
Other specified uses not listed	W	W	43	210
Unspecified: 3/				
Reported	548	3,540	14,200	79,400
Estimated	129	541	8,000	44,000
Total	1,760	13,200	35,300	210,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes slate.
3/ Reported and estimated production without a breakdown by end use.

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TABLE 20
RECYCLED ASPHALT AND CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY REGION 1/

Region/division	Recycled asphalt						Recycled concrete					
	1999			2000			1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Northeast:												
New England	128	$610	$4.77	70	$323	$4.61	84	$570	$6.79	39	$280	$7.18
Middle Atlantic	829	4,110	4.96	235	1,360	5.78	727	3,660	5.03	395	2,130	5.39
Midwest:												
East North Central	69	557	8.07	342	1,730	5.06	236	1,350	5.71	696	3,850	5.53
West North Central	W	W	W	W	W	W	W	W	W	W	W	W
South:												
South Atlantic	W	W	W	W	W	W	247 r/	1,850 r/	7.51 r/	566	4,150	7.34
East South Central	--	--	--	W	W	W	W	W	W	W	W	W
West South Central	--	--	--	W	W	W	--	--	--	W	W	W
West:												
Mountain	97	900	9.28	38	179	4.71	15	58	3.87	41	89	2.17
Pacific	250	1,120	4.50	383	2,820	7.36	340	1,730	5.09	507	3,060	6.03
Total	1,450	7,700	5.32	1,270	7,260	5.73	1,730 r/	9,570 r/	5.54 r/	2,320	13,900	6.01

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 21
RECYCLED ASPHALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999			2000		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alaska 2/	1	$26	$26.00	--	--	--
Arizona	--	--	--	23	$91	$3.96
California	211	933	4.42	354	2,210	6.24
Colorado	W	W	9.65	W	W	6.86
Connecticut	W	W	4.46	W	W	4.43
Florida	W	W	5.56	W	W	5.48
Hawaii	W	W	3.60	--	--	--
Idaho	11	72	6.55	7	38	5.43
Illinois	27	132	4.89	14	73	5.21
Indiana	W	W	10.84	W	W	9.51
Kansas	--	--	--	W	W	1.67
Maine	22	155	7.05	--	--	--
Massachusetts	4	24	6.00	--	--	--
New Hampshire	62	253	4.08	W	W	4.38
New Jersey	718	3,530	4.92	W	W	6.07
New Mexico	5	36	7.20	W	W	W
New York	W	W	5.50	19	77	4.05
North Dakota	W	W	W	W	W	W
Ohio	W	W	W	W	W	W
Oregon	33	147	4.45	W	W	W
Pennsylvania	105	546	5.20	114	657	5.76
South Dakota	W	W	5.26	W	W	2.23
Tennessee	--	--	--	9	40	4.44
Texas	--	--	--	W	W	4.40
Vermont	4	13	3.25	W	W	5.90
Washington	--	--	--	14	50	3.57
Wisconsin	3	15	5.00	240	868	3.62
Total	1,450	7,700	5.32	1,270	7,260	5.73

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 22
RECYCLED CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (thousand metric tons)	1999 Value (thousands)	1999 Unit value	2000 Quantity (thousand metric tons)	2000 Value (thousands)	2000 Unit value
Alabama	W	W	$4.13	W	W	$6.24
Alaska 2/	2	$16	8.00	--	--	--
California	318	1,620	5.08	500	$3,020	6.04
Colorado	W	W	W	W	W	5.50
Connecticut	54	421	7.80	39	278	7.13
Florida	105	879	8.37	142	1,220	8.58
Georgia	--	--	--	W	W	5.31
Hawaii	W	W	6.00	W	W	6.20
Idaho	--	--	--	3	21	7.00
Illinois	W	W	5.99	645	3,740	5.80
Indiana	W	W	3.33	W	W	W
Louisiana	--	--	--	W	W	8.88
Maine	20	88	4.40	--	--	--
Massachusetts	9	55	6.11	--	--	--
Mississippi	W	W	15.00	W	W	11.00
New Hampshire	2	6	3.00	W	W	W
New Jersey	589	3,190	5.42	218	1,330	6.10
New Mexico	15	58	3.87	W	W	1.58
New York	W	W	3.32	W	W	4.47
North Carolina	W	W	11.44	24	199	8.29
North Dakota	2	14	7.00	W	W	W
Ohio	W	W	3.09	W	W	1.43
Oregon	W	W	4.40	W	W	3.50
Pennsylvania	15	60	4.00	25	122	4.88
South Dakota	W	W	4.90	W	W	2.19
Texas	--	--	--	W	W	4.44
Virginia	W	W	6.56	W	W	7.84
Wisconsin	--	--	--	W	W	2.50
Total	1,730 r/	9,570 r/	5.54 r/	2,320	13,900	6.01

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
2/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

TABLE 23
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2000,
BY REGION AND METHOD OF TRANSPORTATION 1/

(Thousand metric tons)

Region/division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	6,130	W	--	W	5,010	24,300	35,700
Middle Atlantic	80,200	W	W	3,530	7,220	74,300	172,000
Midwest:							
East North Central	106,000	W	13,200	W	9,250	146,000	281,000
West North Central	53,200	W	W	W	2,910	96,200	163,000
South:							
South Atlantic	191,000	24,000	5,170	5,340	16,900	143,000	385,000
East South Central	80,200	W	W	W	14,900	65,200	169,000
West South Central	64,500	14,000	--	4,470	8,380	99,600	191,000
West:							
Mountain	24,200	W	--	W	2,520	20,200	53,700
Pacific	34,500	3,270	2,920	5,050	8,070	52,700	107,000
Total	639,000	56,700	38,600	25,400	75,200	722,000	1,560,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 24
CRUSHED AND BROKEN STONE OPERATIONS IN THE UNITED STATES IN 2000, BY STATE

State	Active operations	Active quarries	Dredging operations	Processing plants				Sales yards
				Stationary	Portable	Stationary and portable	None or unspecified	
Alabama	75	67	--	55	8	1	2	9
Alaska 1/	12	12	--	1	8	2	1	--
Arizona	51	55	--	15	31	1	4	--
Arkansas	70	68	--	32	26	3	7	2
California	150	153	1	69	53	11	14	3
Colorado	39	49	--	16	14	6	4	--
Connecticut	22	21	--	17	3	1	--	1
Florida	95	95	1	39	30	11	5	9
Georgia	85	81	--	78	2	--	1	4
Hawaii	21	23	--	11	7	3	--	--
Idaho	54	60	--	9	34	4	7	--
Illinois	143	137	--	77	46	11	1	8
Indiana	90	84	--	67	4	12	--	7
Iowa	205	206	--	33	165	1	3	3
Kansas	100	115	--	25	62	3	10	--
Kentucky	98	96	--	83	4	7	2	2
Louisiana	11	1	--	--	1	--	9	10
Maine	19	21	--	9	8	--	--	2
Maryland	30	30	1	24	3	1	1	--
Massachusetts	37	36	--	22	8	4	1	2
Michigan	33	31	--	17	7	2	5	2
Minnesota	52	62	--	5	40	1	6	--
Mississippi	17	6	--	3	1	1	--	12
Missouri	201	207	--	102	83	10	6	--
Montana	25	28	--	8	14	1	2	--
Nebraska	11	11	--	8	2	1	--	--
Nevada	14	29	--	9	3	1	1	--
New Hampshire	14	18	--	8	3	1	2	--
New Jersey	25	25	--	13	1	10	1	--
New Mexico	40	42	--	13	22	2	3	--
New York	101	101	--	74	10	13	4	--
North Carolina	110	103	--	91	8	1	3	7
North Dakota	5	6	--	--	1	--	4	--
Ohio	114	112	1	87	14	9	1	2
Oklahoma	60	59	--	43	5	8	3	1
Oregon	154	214	2	32	103	5	12	--
Pennsylvania	205	210	1	144	23	16	20	1
Rhode Island	9	9	--	7	2	--	--	--
South Carolina	41	33	--	27	2	2	2	8
South Dakota	11	15	--	9	2	--	--	--
Tennessee	123	124	--	109	7	3	2	2
Texas	172	166	--	94	46	12	2	18
Utah	38	40	--	14	23	--	1	--
Vermont	17	17	--	9	4	2	2	--
Virginia	122	104	--	87	3	9	2	21
Washington	116	164	--	33	51	9	23	--
West Virginia	48	40	--	28	8	1	1	10
Wisconsin	152	174	--	26	113	5	8	--
Wyoming	16	17	--	5	10	--	1	--
Total	3,453	3,577	7	1,787	1,128	207	189	146

-- Zero.

1/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys.

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TABLE 25
U.S. EXPORTS OF CRUSHED STONE IN 2000, BY DESTINATION 1/

(Metric tons, unless otherwise specified)

Destination	Limestone for cement manufacturing	Other	Chalk, crude	Granules, chippings	Total
North America:					
Anguilla	--	51	--	--	51
Bahamas, The	2,720	--	1	307	3,030
Barbados	--	--	--	42	42
Canada	3,870,000	1,690	2,200	87,200	3,960,000
Costa Rica	--	--	--	179	179
Dominican Republic	180	--	--	--	180
Granada	--	--	1	--	1
Guatemala	--	--	1	4	5
Mexico	318	20	26	2,920	3,290
Nicaragua	--	78	--	--	78
Panama	13	--	--	20	33
St. Lucia	--	--	1	--	1
Trinidad and Tobago	--	--	--	36	36
Total	3,880,000	1,840	2,230	90,700	3,970,000
South America:					
Argentina	--	--	1	1,440	1,440
Bolivia	--	--	1	--	1
Brazil	--	--	34	198	232
Colombia	--	--	1	--	1
Ecuador	--	--	125	154	279
Guyana	--	--	--	2	2
Venezuela	--	5	18	449	472
Total	--	5	180	2,240	2,430
Europe:					
Austria	--	--	--	31	31
Belgium	--	113	11	--	124
Denmark	--	1	1	--	2
France	--	41	--	900	941
Germany	97	2,520	--	59	2,680
Ireland	--	1	--	10	11
Italy	--	81	3	443	527
Lithuania	16	--	2	--	18
Netherlands	--	10	11	102	123
Norway	--	--	--	286	286
Spain	398	--	--	--	398
Switzerland	--	295	1	--	296
Turkey	--	--	7	--	7
United Kingdom	--	79	6	169	254
Total	511	3,140	42	2,000	5,690
Asia:					
China	16	57	--	251	324
Hong Kong	90	--	--	116	206
Indonesia	19	--	--	--	19
Japan	--	191	18	40	249
Korea, Republic of	490	1,300	--	537	2,320
Malaysia	47	--	363	--	410
Philippines	287	--	1	--	288
Singapore	--	210	36	2	248
Taiwan	19	7	1	618	645
Thailand	--	--	--	5	5
Total	968	1,760	419	1,570	4,720
Oceania, Australia	5,700	--	16	26,400	32,100
Middle East:					
Israel	--	--	16	24	40
Saudi Arabia	4	--	--	16	20
Total	4	--	16	40	60
Africa:					
Malawi	--	--	18	--	18
South Africa	--	--	--	11	11
Total	--	--	18	11	29

See footnotes at end of table.

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TABLE 25--Continued
U.S. EXPORTS OF CRUSHED STONE IN 2000, BY DESTINATION 1/

(Metric tons, unless otherwise specified)

Destination	Limestone for cement manufacturing	Other	Chalk, crude	Granules, chippings	Total
Grand total	3,880,000	6,740	2,920	123,000	4,020,000
Total value thousands	$11,700	$7,830	$1	$10,100	$29,700

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 26
U.S. IMPORTS OF CRUSHED STONE AND CALCIUM CARBONATE FINES, BY TYPE 1/

Type	1999			2000		
	Quantity (thousand metric tons)	C.i.f. value (thousands)	Unit value	Quantity (thousand metric tons)	C.i.f. value (thousands)	Unit value
Crushed stone and chips:						
Limestone	6,720	$62,200	$9	7,210	$60,100	$8
Limestone for flux or cement manufacturing	3,540	25,000	7	4,190	28,200	7
Quartzite	1	395	395	1	470	470
Other	2,060	17,600	9	1,620	15,900	10
Total	12,300	105,000	XX	13,000	105,000	XX
Calcium carbonate fines: 2/						
Natural chalk	(3/) r/	(3/) r/	--	(3/)	51	--
Calcium carbonates other chalk	1	330	330	1	647	647
Total	1	330	XX	1	698	XX
Grand total	12,300	106,000	XX	13,000	105,000	XX

r/ Revised. XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

2/ Excludes precipitated calcium carbonates.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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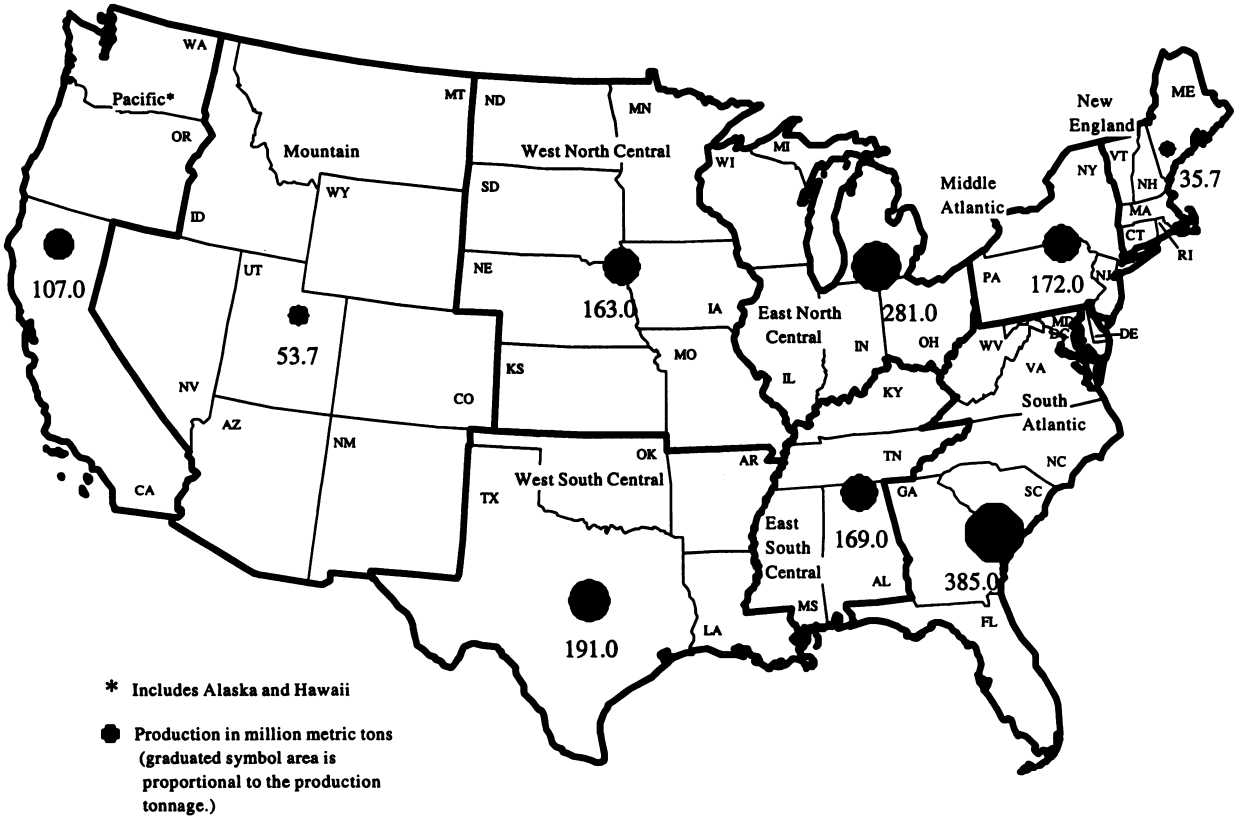
FIGURE 1
PRODUCTION OF CRUSHED STONE IN THE UNITED STATES IN 2000, BY GEOGRAPHIC DIVISION



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STONE, DIMENSION

By Thomas P. Dolley

Domestic survey data and tables were prepared by Aaron J. Poyer, statistical assistant.

Dimension stone can be defined as natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape (Barton, 1968, p. 4). Color, grain texture and pattern, and surface finish of the stone are also normal requirements. Durability (essentially based on mineral composition and hardness and past performance), strength, and the ability of the stone to take a polish are other important selection criteria.

Although various igneous, metamorphic, and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone, and slate. Other varieties of dimension stone that are normally considered to be special minor types include alabaster (massive gypsum), soapstone (massive talc), and various products fashioned from natural stone.

U.S. production of dimension stone in 2000 was estimated to be 1.25 million metric tons (Mt) valued at $235 million—a 7% decrease in value compared with that of 1999. U.S. production of dimension stone in 2000 was the largest amount reported since 1993 and exceeded the 1999 amount by about 2,000 metric tons (t). Exports increased by 9.7% in value to $59.8 million, and imports for consumption increased by 14% in value to $925 million. Apparent consumption was estimated to be $1.1 billion.

In recent years, most dimension stone has been used in construction applications, with the largest portions being sold or used as rough block for building and construction, flagstone, curbing, and ashlars and partially squared pieces. Monumental stone, another major type, includes memorials of various kinds.

Dimension stone production data for the United States are derived by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. quarry producers of rough and dressed dimension stone. Data in this report cover rough crude quarried stone, irregular-shaped and rectangular blocks, and more highly processed stone. A number of other terms also are used to describe further processing, such as "worked," "dressed," "finished," and "manufactured." These and other terms used by the dimension stone industry describe such features as the mineral composition of the rock, the shape of the product, the method of finishing a stone, and the type of finish applied (Stone World, 2000, p. 147-177). No adjustments are made in the data to account for the sometimes substantial losses in processing rough stone into dressed stone. Sold or used data are considered to be equivalent to production because changes in stocks are not surveyed. Of the 228 producing dimension stone operations included in the survey for 2000, 107 (or 47%) responded, which represented 58% of the tonnage; the remaining tonnage was estimated (table 1).

Description and Terminology

There are overlaps between scientific and commercial descriptions of various dimension stone types. The scientific description of dimension stone types is focused primarily on the stone's locality and mineralogical composition, whereas the commercial description is focused primarily on the locality and color of the stone. Furthermore, various combinations of the scientific and commercial descriptions are used by stone producers to effectively market their stone products. The descriptions that follow were adapted from Barton (1968, p. 2-8) and Currier (1960, p. 1-10).

Granite.—Commercial granites include all feldspathic crystalline rocks of mainly interlocking texture and with individual mineral grains that are visible to the naked eye. This category includes rock types such as gneiss, syenite, monzonite, granodiorite, anorthosite, and all other intermediate rock types. Primary colors of granites are white, gray, pink, and red, with green and brown being secondary colors. Black granites (which

Dimension Stone in the 20th Century

Punctuated by labor strikes and high costs and wages, production of all types of dimension stone in the United States in 1900 amounted to 1.6 million metric tons. The top producing State, by value, was Pennsylvania. In the early 20th century, reinforced concrete and structural steel superceded dimension stone as major structural components in buildings. As early as 1906, granite quarriers in the United States expressed concern over the encroachment of substitute materials, such as concrete, on their industry. With the emergence of the automobile, concrete and asphalt were viewed as more suitable materials than dimension stone for road building. In 1931, when the Empire State Building was officially opened, it featured cladding of Indiana limestone and helped in creating a new market for dimension stone as interior and exterior paneling. That same year, U.S. production of dimension stone rose to the highest level of the 20th century—more than 6 million tons. The lowest U.S. production of dimension stone of the 20th century occurred in 1944 during World War II at 649,000 metric tons, owing to a lack of skilled labor, nonessential commodity status, and building construction being at a virtual standstill.

In 2000, production of dimension stone in the United States amounted to about 1.3 million tons. The top producing State, by value, was Indiana. The United States was a significant importer of stone, importing dimension stone valued at more than $1 billion in 2000. Dimension stone was used extensively in home improvements, historic preservation, exterior and interior paneling for buildings, and construction applications. Most dimension stone was sold or used as rough blocks for building and construction, flagstone, curbing, ashlars and partially squared pieces, and monumental and memorial stones.

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are not true granites mineralogically but rather such mafic rocks as diabases, diorites, gabbros, and similar rocks) are also included in this category and range in color from dark gray to black.

Limestone.—Commercial limestones are rocks of sedimentary origin primarily composed of calcium carbonate with or without magnesium. Included in this category are calcitic limestone, dolomite, dolomitic limestone, and travertine (a rock that is chemically precipitated from hot springs).

Marble.—Commercial marble includes metamorphosed limestones and serpentine rocks—all capable of taking a polish. An important member of this classification is serpentine marble, also known as verde antique, and is composed of green-to-black serpentine (a hydrous magnesium silicate mineral), crisscrossed by veins of lighter minerals such as calcite or dolomite.

Sandstone.—Commercial sandstone is a lithified sand composed chiefly of quartz or quartz and feldspar of fragmental (clastic) texture. Sandstone contains interstitial cementing materials, such as silica, iron oxides, calcite, or clay. Arkose (abundant feldspar grains), graywacke (abundant rock fragments), and conglomerates are included in this category. Other members of this category include bluestone (a dense, hard, fine-grained feldspathic sandstone, which splits easily along planes into thin, smooth slabs), brownstone (feldspathic sandstone of brown to reddish-brown color owing to abundant iron oxide), and flagstone (a sandstone or slate that splits into large, thin slabs).

Slate.—Commercial slate is a microgranular metamorphic rock formed by the recrystallization of clay sediments (shale, siltstone, or claystone). Characterized by excellent parallel cleavage, slates may be easily split into relatively thin slabs.

Greenstone.—Commercial greenstones are the result of the metamorphosis of basaltic rocks. Greenstone is named so because of the predominance of greenish minerals, such as chlorite, epidote, or actinolite.

Basalt and Traprock.—Commercial basalt and traprock includes igneous rocks that are too fine grained to be termed black granite. The name traprock is derived from the term "trappa," meaning stairway—the characteristic terraced or steplike appearance of certain basalt lava fields. This category includes both extrusive igneous rocks (such as andesite, basalt, or dacite) and intrusive igneous rocks (such as amphibolites, diabase, diorites, fine grained gabbros, peridotites, and pyroxenites).

Miscellaneous.—This category includes dimension stone types that do not easily fall into the aforementioned categories, such as soapstone, talc, or steatite (rocks containing various amounts of talc). Additional miscellaneous dimension stones include diatomite, mylonites, pumice, schist, tripoli, tuff, porous or scoriaceous volcanic rocks, or any other rocks used as building stones.

Production

Rough stone blocks split or cut from a quarry face are transported to processing plants, frequently located at the quarry site, at least for preliminary sizing. Further dressing, including final sizing and finishing operations, such as polishing, edging, and decorating, also may be done at the quarry site.

In 2000, limestone accounted for 432,000 t (or 35%) of the total domestic dimension stone production of 1.25 Mt, followed by granite (33%), sandstone (18%), miscellaneous stone (9%), marble (3%), and slate (2%). Granite accounted for about $112 million (or 48%) of total domestic production of $235 million, followed by limestone (28%), sandstone (10%), slate (6%), miscellaneous (5%), and marble (3%).

Production was reported in 34 States and Puerto Rico. Leading producer States, in descending order by tonnage, were Indiana, Vermont, Wisconsin, Texas, and Georgia. These States accounted for 48% of the domestic production. The leading producer States, in descending order by value, were Indiana, Vermont, Minnesota, South Dakota, and North Carolina. These States contributed 49% of the value of domestic production (table 3).

The top five producing companies, listed alphabetically, were Buechel Stone Corp. in Wisconsin; Cold Spring Granite Co. in California, Minnesota, New York, Oklahoma, South Dakota, and Texas; Fletcher Granite Co., Inc., in Massachusetts and New Hampshire; Oolitic Victor Stone Co. in Indiana; and Rock of Ages Corp. in New Hampshire and Vermont. These companies produced about 27% of domestic production in tonnage and about 31% of production in value. The leading 14 companies accounted for 45% of total domestic tonnage and 47% of the value.

Granite.—Dimension granite was produced by 38 companies operating 70 quarries in 20 States. Production was 415,000 t valued at $112 million. Granite production tonnage decreased by 5% and value decreased by 3% compared with that of 1999. The top five producing States, in descending order by tonnage, were Massachusetts, Georgia, New Hampshire, South Dakota, and Idaho. Massachusetts accounted for 17% of the tonnage of U.S. granite production. Massachusetts and Georgia combined accounted for 23% of the value of the U.S. granite production (table 4).

The leading producers were Cold Spring Granite, Fletcher Granite, and Rock of Ages accounting for over one-half of U.S. granite production in tonnage and value.

Limestone.—Dimension limestone was produced by 30 companies from 34 quarries in 10 States. Production decreased by 3% to 432,000 t from 446,000 t in 1999, and the value decreased by 18% to $65.2 million from $79.1 million in 1999. The top five producing States, in descending order by tonnage, were Indiana, Wisconsin, Texas, Minnesota, and Kansas. Indiana produced 53% of the U.S. tonnage and 49% of the value (table 5).

The leading producers were Buechel Stone; Independent Limestone Co.; Indiana Limestone Co., Inc.; Oolitic Victor Stone; and Texas Stone Quarries. These firms accounted for 59% of total U.S. tonnage and about 42% of the value.

Sandstone.—Dimension sandstone was produced by 28 companies operating 33 quarries in 16 States. Production increased to 229,000 t in 2000 from 197,000 t in 1999. The value decreased by 12% to $22.9 million in 2000 from $25.9 million in 1999. The top five producing States, in descending order by tonnage, were New York, Arizona, Ohio, California, and Michigan. New York was the leading producing State with 25% of the tonnage and 19% of the value (table 6).

The leading producers were American Sandstone, Finger Lakes Stone Co. Inc., Waller Brothers Stone Co., Jude Stone Quarry Co., and Ulti-Solutions Inc. These companies accounted for about 67% of the tonnage and 58% of the value of domestic production.

Marble.—Marble was mined by six companies operating eight quarries in five States. Production declined to 31,300 t valued at $7.2 million from 38,300 t valued at $8.6 million in 1999 (table 10). Vermont was the leading producing State, followed by Georgia, Tennessee, Colorado, and Alabama. The leading producers were Vermont Quarries Co., Georgia Marble

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Co., and Tennessee Marble Co. Additional data have been withheld to avoid disclosing company proprietary information.

Slate.—Slate was produced by 14 companies operating 20 quarries in 5 States. Production increased slightly to 28,700 t in 2000 from 28,600 t in 1999. The value increased by 1% to $14.2 million in 2000 from $14 million in 1999 (table 12). The producing States, in descending order by tonnage, were Vermont, Pennsylvania, New York, North Carolina, and California. The leading producers were U.S. Quarried Slate Products Inc., McAlpine Alfred Inc., Dally Slate Co., Ritchie Bros. Slate Co., and Quarry Slate Industries Inc. Additional data have been withheld to avoid disclosing company propriety information.

Consumption

Rough stone represented 55% of the tonnage and 46% of the value of all dimension stone sold or used by domestic producers, including exports. The largest uses of rough stone were in construction (50%) and irregular-shaped stone (19%) applications, by tonnage. Dressed stone represented 45% by tonnage and 54% by value of the total stone sold or used. The largest uses of dressed stone, by tonnage, were in flagging (28%), ashlars and partially squared pieces (20%), and curbing (10%) (table 7).

Uses for the different varieties of dimension stone varied considerably. The major uses of granite sold or used in 2000, by tonnage, were in rough blocks for construction (24%), monumental rough stone (21%), curbing (13%), monumental dressed stone (7%), and ashlars and partial squared pieces (6%) (table 8). Primary uses of limestone, by tonnage, were in rough blocks for building and construction (45%) and irregular-shaped stone (14%) (table 9). Primary uses of marble, by tonnage, were rough blocks for building and construction (44%) and dressed slabs and blocks for building and construction (13%) (table 10). Primary uses of sandstone, by tonnage, were in dressed stone for flagging (59%) and rough blocks for building and construction (12%) (table 11). Dimension slate sold or used by producers in the United States in 2000, by tonnage, was principally for roofing (38%), flooring (37%), and flagging (8%) (table 12).

Overall, the apparent consumption of dimension stone in the United States was estimated to be $1.1 billion in 2000, an increase of 8% compared with that of 1999. Apparent consumption is defined as production plus imports for consumption minus exports. Value data are used in the apparent consumption calculation because tonnage data are not available for imports and exports. Additionally, changes in industry stocks are not considered because the data are not available.

Prices

The average 2000 value for dimension stone was $188 per metric ton—a decrease of 7.8% from that of 1999, based on the USGS survey. The average unit values for different types of dimension stone were granite, $270 per ton; limestone, $151 per ton; sandstone, $100 per ton; marble, $228 per ton; and slate, $495 per ton. Price data that are available show considerable variation. Prices are substantially different not only for the kind of stone but also for the appearance of the same kind of stone. Color, grain structure, and finish contribute significantly to price and marketability.

Foreign Trade

Exports.—In 2000, total exports of dimension stone increased in value by about 9% to about $60 million compared with those of 1999; granite accounted for 58% of the export value. The largest share of granite was exported to China (table 13).

Imports.—The value of imports for consumption of dimension stone types increased in 2000 by about 14% to $925 million. Italy continued to be the major single source of granite, accounting for 42% of granite imports. Other important granite import sources included Brazil (18%), India (13%), and Canada (11%) (table 14). Italy also was a major source of rough and dressed marble, slate, and travertine imports (tables 15, 16). Duties on imported dimension stone are listed in table 2.

World Review

World dimension stone production, excluding the United States, was estimated to be approximately 60 Mt in 1999, and preliminary numbers indicated that this total was unchanged for 2000. Although some small-scale production probably occurred in the majority of the world's nations, dimension stone was produced and officially reported in about 34 countries. The top five producing countries in 1999, in descending order by tonnage, were China, Italy, India, Iran, and Spain. These countries accounted for about 72% of the world production. The United States ranked 10th in world production of dimension stone in 1999 (Internazionale Marmi e Macchine Carrara S.p.A., [2001], International quarry production, accessed August 27, 2001, at URL http://www.immcarrara.com/stat/english-version/index-stone-sector.html).

Outlook

The U.S. dimension stone industry has experienced renewed growth in the past 2 to 3 years, but the economic slowdown in late 2000 and early 2001 has reduced domestic production backlogs for most stone types. However, industry experts anticipate growth in dimension stone sales during the near term because of improved technology and variety and the increased costs of alternative construction materials. Additionally, for residential and office building construction, growth in the use of dimension stone is expected in new prestige markets for home improvement, as well as in renovations to attract and keep tenants.

References Cited

Barton, W.R., 1968, Dimension stone: U.S. Bureau of Mines Information Circular 8391, 147 p.

Currier, L.W., 1960, Geologic appraisal of dimension-stone deposits: U.S. Geological Survey Bulletin 1109, 78 p.

Stone World, 2000, Stone world buyers guide: Stone World, v. 17, no. 11, November, p. 147-177.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Stone, Dimension. Ch. in Mineral Commodity Summaries, annual.

Stone, Dimension. Ch. in Minerals Yearbook, annual.

Construction Stone. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

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Other

American Monument Association, Columbus, OH.
Barre Granite Association, Barre, VT.
Building Stone Magazine (Quarterly). Building Stone Institute, Purdys, NY.
Dimension stone. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Dimension Stone. U.S. Bureau of Mines Information Circular 8391, 1986.
Dimensional Stone. Ashlee Publishing Co., Inc., New York, (monthly).
Elberton Granite Association, Inc., Elberton, GA.
Indiana Limestone Institute of America Inc., Bedford, IN.
Industrial Minerals. Metal Bulletin plc, London (monthly, with particular references in July 1984, February 1991, November 1991, and February 1996).
Marble Institute of America, Columbus, OH.
Stone, Decorative. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Stone, Dimension. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 6th ed., Donald Carr, ed., 1994.
Stone, Dimension. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Stone World. Business News Publishing Co., Troy, MI, (monthly).

TABLE 1
SALIENT U.S. DIMENSION STONE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
Sold or used by producers: 2/					
Quantity	1,150	1,180	1,140	1,250	1,250
Value	234,000	225,000	225,000	254,000 r/	235,000
Exports (value)	49,500	54,800	59,600	54,500	59,800
Imports for consumption (value)	462,000	548,000	698,000	808,000	925,000

r/ Revised.
1/ Data are rounded to no more than three significant digits.
2/ Includes Puerto Rico and other U.S. possessions and territories.

TABLE 2
U.S. IMPORT DUTIES ON DIMENSION STONE

Tariff item	HTS. No.	Normal trade relations (NTR) January 1, 2000	Non-NTR January 1, 2000
Slate, rough blocks or slabs	2514.00.0000	Free	25% ad valorem.
Rough blocks or slabs of marble, travertine, other calcareous monumental or building stone:	2515.00.0000		
Marble and travertine:			
Crude or roughly trimmed	2515.11.0000	do.	$22.95 per cubic meter.
Marble, merely cut	2515.12.1000	do.	13% ad valorem.
Travertine, merely cut	2515.12.2000	3.0% ad valorem	50% ad valorem.
Other calcareous stone alabaster	2515.20.0000	do.	Do.
Rough blocks or slabs of granite, porphyry, basalt, sandstone, other monumental of building stone:	2516.00.0000		
Granite:			
Crude of roughly trimmed	2516.11.0000	Free	$8.83 per cubic meter.
Merely cut	2516.12.0000	2.8% ad valorem	60% ad valorem.
Sandstone:			
Crude of roughly trimmed	2516.21.0000	Free	$5.30 per cubic meter.
Merely cut	2516.22.0000	3.0% ad valorem	50% ad valorem.
Other monumental or building stone	2516.90.0000	do.	Do.
Setts, curbstones, flagstones:	6801.00.0000	2.8% ad valorem	60% ad valorem.
Worked monumental or building stone	6802.00.0000		
Tiles and cubes under 7 centimeters square, granules	6802.10.0000	4.8% ad valorem	40% ad valorem.
Other stone and srticles with a flat or even surface:			
Marble, travertine, and alabaster:	6802.21.0000		
Travertine	6802.21.1000	4.2% ad valorem	50% ad valorem.
Other	6802.21.5000	1.9% ad valorem	13% ad valorem.
Other calcareous stone	6802.22.0000	4.9% ad valorem	50% ad valorem.
Granite	6802.23.0000	3.7% ad valorem	60% ad valorem.
Other stone	6802.29.0000	6.0% ad valorem	30% ad valorem.
Other:			
Marble, travertine, alabaster:	6802.91.0000		
Marble:			
Slabs	6802.91.0500	2.5% ad valorem	15% ad valorem.

See footnotes at end of table.

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TABLE 2--Continued
U.S. IMPORT DUTIES ON DIMENSION STONE

Tariff item	HTS. No.	Normal trade relations (NTR) January 1, 2000	Non-NTR January 1, 2000
Setts, curbstones, flagstones--Continued:			
Other stone and srticles with a flat or even surface--Continued:			
Other--Continued:			
Marble, travertine, alabaster--Continued:	6802.91.0000		
Marble--Continued:			
Other	6802.91.1500	4.9% ad valorem	50% ad valorem.
Travertine articles of subheading 6802.21.1000 that have been dressed or polished, but not further worked:	6802.91.2000	4.2% ad valorem	Do.
Other	6802.91.2500	3.7% ad valorem	40% ad valorem.
Alabaster	6802.91.3000	4.7% ad valorem	50% ad valorem.
Other calcareous stone:	6802.92.0000	4.9% ad valorem	Do.
Granite	6802.93.0000	3.7% ad valorem	60% ad valorem.
Other stone	6802.99.0000	6.5% ad valorem	40% ad valorem.
Worked slate and articles:	6803.00.0000		
Roofing slate	6803.00.1000	3.3% ad valorem	25% ad valorem.
Other	6803.00.5000	Free	Do.

TABLE 3
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Alabama	7,210	$2,380	W	W
California	29,400	4,930	33,300	$5,790
Colorado	14,700	3,430	W	W
Georgia	83,400	12,200	74,200	11,400
Idaho	39,300	5,510	W	W
Indiana	255,000	33,500	235,000	32,400
Kansas	16,100	1,640	14,100	1,890
Maryland	26,000	3,150 r/	28,700	3,560
Massachusetts	70,400	16,900	69,600	16,800
Minnesota	42,700	20,700	W	W
Montana	9,500	1,440	W	W
New Mexico	17,900	2,320	W	W
New York	49,300	8,940	62,200	5,780
North Carolina	54,700	17,700	40,500	16,800
Ohio	25,600	2,390	34,500	3,050
Oklahoma	3,480	635	5,910	1,530
Pennsylvania	50,800	12,600	49,500	12,100
South Carolina	9,230	855	W	W
Texas	82,500	24,200	84,700	11,500
Vermont	98,600	25,600	103,000	26,600
Virginia	5,640	624	W	W
Wisconsin	85,500	13,400	93,100	11,700
Other 2/	175,000 r/	39,300 r/	326,000	73,900
Total	1,250,000	254,000 r/	1,250,000	235,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Arizona, Arkansas, Connecticut, Maine, Michigan, Missouri, New Hampshire, South Dakota, Tennessee, Utah, Washington, West Virginia, Puerto Rico and other U.S. possessions and territories, and States indicated by symbol W.

TABLE 4
DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
California	9,420	$1,830	9,220	$1,820
Georgia	76,100	10,200	66,700	9,220
Massachusetts	70,400	16,900	69,600	16,800

See footnotes at end of table.

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TABLE 4--Continued
DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
North Carolina	53,100	16,900	W	W
South Carolina	9,230	855	9,230	855
Wisconsin	2,860	2,480	2,360	1,170
Other 2/	216,000	66,100	258,000	81,900
Total	437,000	115,000	415,000	112,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Idaho, Maine, Minnesota, Missouri, Montana, New Hampshire, New Mexico, New York, Oklahoma, Pennsylvania, South Dakota, Texas, Vermont, Virginia, Puerto RIco and other U.S. possessions and territories, and States indicated by symbol W.

TABLE 5
DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Indiana	252,000	$33,500	233,000	$32,300
Kansas	15,200	1,510	13,000	1,790
Wisconsin	72,600	10,000	72,600	10,000
Other 2/	106,000	34,100 r/	113,000	21,100
Total	446,000	79,100 r/	432,000	65,200

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Alabama, Arkansas, California, Minnesota, Ohio, Texas, Vermont, and Puerto Rico and other U.S. possessions and territories.

TABLE 6
DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
New York	44,900	$7,370	57,600	$4,350
Pennsylvania	17,100	2,490	15,800	827
Other 2/	135,000	16,000	156,000	17,800
Total	197,000	25,900	229,000	22,900

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Alabama, Arizona, Arkansas, California, Colorado, Idaho, Kansas, Michigan, New Mexico, North Carolina, Ohio, Oklahoma, West Virginia, and Wisconsin.

TABLE 7
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Rough stone:				
Rough blocks for building and construction	345,000	$47,000	349,000	$46,400
Irregular-shaped stone	143,000	13,100	134,000	13,300
Monumental	133,000	25,000	93,400	18,700
Other 3/	87,200	17,900	115,000	30,000
Dressed stone:				
Ashlars and partially squared pieces	103,000	22,600	113,000	24,200
Slabs and blocks for building and construction	52,300	11,000	30,800	5,960
Monumental	39,000	20,500	37,000	18,500
Curbing	52,900	22,900	55,700	22,800
Flagging	134,000	14,700	160,000	12,600
Flagging (slate)	2,110	434	2,400	585
Roofing slate	10,300	6,900	10,800	6,690

See footnotes at end of table.

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TABLE 7--Continued
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Dressed stone--Continued:				
Structural and sanitary	2,050	2,810	2,040	2,830
Flooring slate	10,600	2,140	10,700	2,190
Other 4/	137,000 r/	47,400 r/	139,000	30,100
Total	1,250,000	254,000 r/	1,250,000	235,000

r/ Revised.
1/ Includes Puerto Rico and other U.S. possessions and territories.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes flagging (2000), exports, uses not specified, and uses not listed.
4/ Includes panels and veneer, tile, blackboards, exports, uses not specified, and uses not listed.

TABLE 8
DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Rough stone:				
Rough blocks for building and construction	90,800	$18,000	99,200	$18,600
Irregular-shaped stone	4,540	173	4,360	108
Monumental	126,000	23,400	89,400	18,300
Other 2/	53,700	11,400	57,800	14,200
Dressed stone:				
Ashlars and partially squared pieces	25,700	10,200	27,700	10,400
Slabs and blocks for building and construction	1,290	225	1,620	619
Monumental	33,400	18,700	32,100	17,000
Curbing	52,600	22,900	54,800	22,700
Other 3/	48,700	10,400	48,200	9,820
Total	437,000	115,000	415,000	112,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes exports and uses not listed.
3/ Includes panels and veneer, tile, uses not specified, and uses not listed.

TABLE 9
DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Rough stone:				
Rough blocks for building and construction	208,000	$24,100	196,000	$22,100
Irregular-shaped stone	60,100	4,110	59,900	4,270
Other 2/	30,800	6,140 r/	29,900	5,550
Dressed stone:				
Ashlars and partially squared pieces	50,600	8,320	57,300	10,000
Slabs and blocks for building and construction	44,000	8,800 r/	22,700	3,670
Flagging	5,920	483	9,060	1,050
Other 3/	46,200	27,200 r/	57,000	18,500
Total	446,000	79,100 r/	432,000	65,200

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes exports, monumental stone (2000), and uses not listed.
3/ Includes curbing (2000), monumental stone (1999), panels and veneer, tile, uses not specified, and uses not listed.

TABLE 10
DIMENSION MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Rough stone:				
Rough blocks for building and construction	11,500	$2,400	13,800	$2,730
Other 3/	7,430	1,870	2,630	364

See foonotes at end of table.

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TABLE 10--Continued
DIMENSION MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Dressed stone:				
Slabs and blocks for building and construction	4,080	1,180	4,190	1,020
Monumental	4,950	1,400	W	W
Flagging	444	29	W	W
Tile	6,380	1,650	W	W
Other 4/	3,520 r/	73 r/	10,600	3,030
Total	38,300 r/	8,600 r/	31,300	7,150

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Dressed stone: Other."
1/ Includes Puerto Rico.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes monumental, uses not specified, and uses not listed.
4/ Includes flagging (2000), monumental (2000), panels and veneer, ashlars and partially squared pieces, tile (2000), and uses not listed.

TABLE 11
DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Rough stone:				
Rough blocks for building and construction	28,900	$2,160	28,400	$1,990
Irregular-shaped stone	9,020	1,180	10,400	1,210
Other 2/	--	--	785	214
Dressed stone:				
Ashlars and partially squared pieces	11,700	1,630	17,500	2,390
Slabs and blocks for building and construction	2,880	761	2,190	592
Flagging	112,000	12,900	136,000	10,300
Other 3/	32,400	7,230	33,700	6,260
Total	197,000	25,900	229,000	22,900

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes flagging and uses not listed.
3/ Includes panels and veneer, tile, curbing, exports, uses not specified, and uses not listed.

TABLE 12
DIMENSION SLATE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Flagging	2,110	$434	2,400	$585
Roofing	10,300	6,900	10,800	6,690
Structural and sanitary purposes	2,050	2,810	2,040	2,830
Flooring	10,600	2,140	10,700	2,190
Other 2/	3,560	1,700	2,660	1,910
Total	28,600	14,000	28,700	14,200

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes blackboards (1999), uses not specified, and uses not listed.

TABLE 13
U.S. EXPORTS OF DIMENSION STONE, BY TYPE 1/

(Thousand metric tons and thousand dollars)

Type	1999 Quantity	1999 Value	2000 Quantity	2000 Value	Major destination in 2000, percentage 2/
Marble, travertine, alabaster worked 3/	33	4,770	20	3,740	Jamaica, 34%.
Marble, travertine--crude or roughly trimmed	1	725	2	879	Canada, 43%.
Marble, travertine--merely cut, by sawing or otherwise 4/	4	2,030	11	1,590	Bahamas, 25%.

See footnotes at end of table.

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TABLE 13--Continued
U.S. EXPORTS OF DIMENSION STONE, BY TYPE 1/

(Thousand metric tons and thousand dollars)

Type	1999 Quantity	1999 Value	2000 Quantity	2000 Value	Major destination in 2000, percentage 2/
Granite, crude or roughly trimmed	150	25,900	116	29,500	China, 30%.
Granite, merely cut by sawing or otherwise 4/	16	6,430	18	5,910	Italy, 28%.
Sandstone, crude or roughly trimmed	5	570	3	545	Canada, 71%.
Sandstone, merely cut, by sawing or otherwise 4/	6	1,250	5	1,220	Canada, 91%.
Slate, worked and articles of slate	NA	8,760	NA	10,700	Belize, 41%.
Slate, whether or not roughly trimmed or merely cut 4/	NA	504	NA	682	Canada, 81%.
Other calcareous monumental or building stone; alabaster 5/	8	2,170	8	2,170	Canada, 48%.
Other monumental or building stone 6/	8	1,430	14	2,900	Canada, 70%.
Total	XX	54,500	XX	59,800	

NA Not available. XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ By value.
3/ Further worked than simply cut with a flat surface.
4/ Blocks or slabs.
5/ Crude, roughly trimmed, or merely cut into blocks or slabs. Other than marble and travertine (includes alabaster).
6/ Crude, roughly trimmed, or merely cut into blocks or slabs. Other than calcareous stone and alabaster, granite, sandstone, slate, dolomite, quartzite, and steatite.

Source: U.S. Census Bureau.

TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF DIMENSION GRANITE, BY COUNTRY 1/

(Thousand dollars)

Country	Rough granite 3/	Dressed: Worked granite: Simply cut 4/	Dressed: Worked granite: Not cut to size 5/	Dressed: Worked granite: Cut to size 2/: Maximum 1.5 centimeters	Dressed: Worked granite: Cut to size 2/: 1.5-7.5 centimeters	Dressed: Worked granite: Cut to size 2/: Monumental minimum 7.5 centimeters	Dressed: Worked granite: Cut to size 2/: Building minimum 7.5 centimeters	Dressed: Worked granite: Other	Dressed: Total worked	Total dressed
1999:										
Argentina	2	16	303	--	822	--	71	153	1,350	1,370
Brazil	1,610	3,480	7,190	1,850	24,400	185	1,970	8,690	44,300	47,800
Canada	3,940	1,720	153	2,170	13,600	5,470	10,700	5,120	37,200	38,900
China	728	2,090	1,030	2,580	4,700	1,200	2,340	7,100	19,000	21,000
Finland	14	--	--	--	--	--	--	111	111	111
India	2,720	3,220	1,890	6,790	12,800	4,330	2,320	5,220	33,300	36,500
Italy	3,800	11,800	26,900	8,440	56,400	575	12,700	26,300	131,000	143,000
Japan		16	--	--	2	--	--	--	2	18
Mexico	23	254	49	21	2,210	--	823	11	3,120	3,370
Norway	13	--	--	36	178	20	--	--	234	234
Portugal	32	141	--	--	125	--	5	101	231	372
Saudi Arabia	217	55	115	28	603	--	36	161	943	998
South Africa	1,860	224	--	24	364	--	25	185	598	822
Spain	214	842	1,770	859	7,260	3	1,750	2,310	13,900	14,800
Other	893	679	1,170	344	2,750	55	1,030	1,110	6,460	7,140
Total	16,100	24,500	40,600	23,100	126,000	11,800	33,800	56,600	292,000	317,000
2000:										
Argentina	--	36	219	16	837	--	66	180	1,320	1,350
Brazil	2,160	5,140	12,100	2,920	37,500	409	3,790	12,900	69,600	74,800
Canada	4,810	1,050	139	2,730	17,600	6,440	10,400	5,800	43,100	44,100
China	1,170	2,990	1,020	3,930	7,890	1,720	3,790	8,430	26,800	29,800
Finland	19	--	--	--	47	--	13	48	108	108
India	1,140	3,980	3,030	6,580	18,700	4,530	7,310	7,670	47,800	51,700
Italy	3,240	10,600	29,500	8,160	79,800	499	17,200	28,700	164,000	174,000
Japan	10	10	--	5	12	39	--	27	84	94
Mexico	148	192	41	115	2,320	--	348	136	2,960	3,150
Norway	94	6	16	--	82	--	7	--	106	112
Portugal	47	96	19	77	63	--	61	77	297	393
Saudi Arabia	50	111	76	39	1,180	--	69	155	1,520	1,640

See footnotes at end of table.

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TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF DIMENSION GRANITE, BY COUNTRY 1/

(Thousand dollars)

Country	Rough granite 3/	Dressed: Simply cut 4/	Dressed: Worked granite: Not cut to size 5/	Dressed: Worked granite: Cut to size 2/: Maximum 1.5 centimeters	1.5-7.5 centimeters	Monumental minimum 7.5 centimeters	Building minimum 7.5 centimeters	Other	Total worked	Total dressed
2000--Continued:										
South Africa	1,640	343	45	--	372	30	68	48	563	906
Spain	294	642	2,700	1,130	10,100	30	2,170	1,610	17,700	18,400
Other	1,470	804	4,450	580	5,320	56	1,130	2,880	14,400	15,200
Total	16,300	26,000	53,400	26,300	182,000	13,800	46,400	68,700	390,000	416,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ One or more faces worked more than simply cut.

3/ Normal quarry products. Includes crude or roughly trimmed and roughly cut by sawing or otherwise. Harmonized Tariff Schedule of the United States (HTS) codes 2516.11.0000, 2516.12.0030, and 2516.12.0060.

4/ Simply cut with a flat even surface. HTS code 6802.23.0000.

5/ Only one face worked more than simply cut. HTS code 6802.93.0010.

Source: U.S. Census Bureau.

TABLE 15
U.S. IMPORTS FOR CONSUMPTION OF MAJOR CATEGORIES OF DIMENSION MARBLE AND OTHER CALCAREOUS STONE, BY COUNTRY 1/

Country	Dressed marble, slabs 2/: Quantity (metric tons)	Value (thousands)	Dressed marble, other 3/: Quantity (metric tons)	Value (thousands)	Other dressed calcareous stone 4/: Quantity (metric tons)	Value (thousands)	Rough marble 5/: Quantity (metric tons)	Value (thousands)
1999:								
China	4,830	$2,910	6,120	$6,340	7,740	$5,000	75	$98
France	104	182	161	175	20,100	18,400	3	7
Greece	4,820	4,960	5,050	5,820	24,300	3,600	214	163
India	805	728	1,120	1,260	2,010	770	63	59
Italy	43,200	37,600	57,300	58,700	80,400	55,100	2,490	2,560
Mexico	609	780	8,250	7,630	11,300	10,700	243	303
Portugal	940	733	1,930	1,570	14,000	7,800	138	91
Spain	8,720	5,770	22,700	19,700	65,900	38,100	740	1,050
Taiwan	1,050	1,180	4,620	8,450	1,420	645	45	57
Turkey	3,740	3,120	5,270	3,760	6,100	3,760	120	134
Other	5,970	5,530	8,950	10,200	57,100	24,300	8,190	1,250
Total	74,700	63,500	121,000	124,000	290,000	168,000	12,300	5,770
2000:								
China	6,750	3,610	11,100	9,140	14,300	4,990	717	215
France	306	239	295	422	69,100	23,200	28	42
Greece	4,910	5,160	7,230	6,380	13,400	4,070	75	68
India	743	792	1,410	2,250	1,680	1,190	30	41
Italy	43,900	44,400	62,900	64,700	115,000	67,600	2,800	3,270
Mexico	1,020	1,030	7,140	7,180	14,700	12,700	172	174
Portugal	1,650	1,290	1,640	1,390	13,900	9,540	50	30
Spain	9,010	6,580	27,800	21,300	86,500	40,800	296	260
Taiwan	1,120	1,260	3,830	6,370	2,290	998	37	79
Turkey	4,400	3,840	6,620	4,970	7,580	5,410	250	407
Other	7,770	7,320	10,900	11,700	96,000	31,600	1,060	938
Total	81,600	75,500	141,000	136,000	434,000	202,000	5,510	5,520

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Worked more than simply cut with a flat surface. Harmonized Tariff Schedule of the United States (HTS) code 6802.91.0500.

3/ Merely cut by sawing or otherwise.

4/ Worked more than simply cut with a flat surface. Other than marble and travertine. HTS code 6802.92.0000.

5/ Simply cut by sawing or otherwise into rectangular blocks or slabs. HTS code 2515.12.1000.

Source: U.S. Census Bureau as modified by the U.S. Geological Survey.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF DIMENSION STONE, BY TYPE 1/

Type		1999 Quantity	1999 Value (thousands)	2000 Quantity	2000 Value (thousands)	Major source in 2000, percentage 2/
Calcareous stone, other 3/	metric tons	32,100	$5,120	5,500	$4,010	Mexico, 46%.
Marble and alabaster 4/	do.	16,600	11,000	11,200	9,590	Italy, 37%.
Sandstone, cut, by sawing or otherwise 5/	do.	497	224	342	222	Italy, 44%.
Slate, roofing	million square feet	10	6,660	19	9,950	Canada, 31%.
Slate, roughly trimmed or simply cut 5/	do.	5,000	2,140	7,890	3,090	China, 37%.
Slate, worked and articles of slate, and other 6/	do.	NA	50,600	NA	57,900	India, 37%.
Travertine, monumental or building stone and articles thereof 7/	do.	28,700	15,100	29,000	17,400	Italy, 49%.
Travertine, worked monumental or building stone 8/	do.	59,100	34,900	59,000	44,500	Italy, 43%.
Other stone-monumental or building stone 9/	do.	10,800	4,310	10,100	4,110	Italy, 23%.

NA Not available.

1/ Data are rounded to no more than three significant digits. Does not include totals shown on tables 14 and 15.

2/ By value.

3/ Other than marble, travertine, and alabaster. Simply cut with a flat surface.

4/ Simply cut with a flat surface.

5/ Rectangular blocks or slabs.

6/ Other than roofing, including agglomerated slate.

7/ Simply cut with a flat surface. Other than tiles and granules.

8/ Dressed or polished but not further worked.

9/ Simply cut with a flat surface. Other than granite, calcareous stone, alabaster, slate, dolomite, quartzite, and steatite.

Source: U.S. Census Bureau.

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STRONTIUM

By Joyce A. Ober

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Strontium occurs commonly in nature, averaging 0.034% of all igneous rock; only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), however, contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient enough size to make development of mining facilities attractive. Strontianite would be the more useful of the two common minerals because strontium is used most often in the carbonate form, but few deposits have been discovered that are suitable for development. A mine in China is believed to be the only developed strontianite deposit in the world (Hong, 1993).

Chemical Products Corp. (CPC) of Cartersville, GA, was the only U.S. producer of strontium compounds from celestite. CPC produced strontium carbonate from imported Mexican ore; no celestite mines were active in the United States.

Legislation and Government Programs

Government stockpiling of celestite began in 1942 to provide a secure supply for the production of strontium compounds required for defense applications during World War II. Celestite purchase specifications issued in 1960 for the national defense stockpile established quality requirements of greater than 95% strontium sulfate content with less than 1.5% calcium sulfate and less than 2% barium sulfate (U.S. Department of Defense, 1960).

In 1963, Congress determined that the celestite stockpile was unnecessary, and the General Services Administration began selling stockpiled material. All stockpile-grade celestite was sold by 1973. The remaining material graded less than 91% strontium sulfate and more than 4% calcium sulfate and some with more than 10% barium sulfate (Defense Logistics Agency, 1998).

In 2000, the stockpile contained approximately 12,000 metric tons (t) of celestite, all of which was authorized by Congress for disposal. The low quality of the material remaining in the stockpile made it undesirable as raw material for strontium carbonate production. Reports issued by the Defense National Stockpile Center of the Defense Logistics Agency, the agency now responsible for managing stockpile sales, listed the celestite as valueless.

Production

Although celestite mines have not been active in the United States since 1959, deposits have been identified nationwide. During World War II, celestite resources were mined in California and Texas; at that time, mines had been inactive since World War I, and strontium minerals were imported to satisfy

Strontium in the 20th Century

In 1900, no strontium minerals or chemicals were produced in the United States. Domestic production of celestite, a strontium sulfate ore, did not take place until 1916 when 250 metric tons containing approximately 100 tons of strontium were produced. Domestic and imported ores were used to produce strontium carbonate and strontium nitrate for use in fireworks, signal flares, refrigeration, steelmaking, and sugar beet processing. World War I created a demand for strontium nitrate for such military uses as tracer bullets and various types of flares. At the end of the war, demand decreased significantly. Domestic mining was inactive until the beginning of World War II, when military activities increased demand at the same time supply of imported ores from overseas was disrupted. Domestic production from California and Texas, with additional supplies from Mexico, were used to meet the demand with the few shipments that were available from the United Kingdom. During this time, celestite from Texas was used in drilling mud, substituting for barite, which was in short supply because of increased requirements for the war effort. The end of hostilities brought the collapse of the domestic celestite industry. The use of celestite in drilling muds ended at about the same time.

In the strontium chemical industry, domestic celestite could not compete in quality or price with imports from Mexico, Spain, and the United Kingdom. Domestic mining was minimal and sporadic until 1959 when it ceased completely. Uses for strontium chemicals for corrosion inhibitors, depilatories, greases, luminous paints, medicines, metallurgy, optics, and plastics increased slightly. In 1967, strontium ferrite ceramic magnets were developed. In 1969, strontium replaced barium in color television faceplate glass to block x-ray emissions, causing tremendous growth in the demand for strontium carbonate. By 1971, television glass was the largest end use for any strontium chemical and remained so through the end of the century, with its share of the strontium market increasing. Other uses were developed for strontium, but all were dwarfed by the chemical's consumption in television glass.

In 2000, U.S. apparent consumption was about 36,000 tons of contained strontium, about 77% of which was used in television glass and 10% in ferrite magnets. Pyrotechnic uses remained significant, accounting for an estimated 9% of total consumption. Other uses included the electrolytic production of zinc and applications in pigments and fillers.

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domestic demand.

The sole U.S. strontium carbonate producer voluntarily provided domestic production and sales data to the U.S. Geological Survey (USGS). Production and stock data, however, have been withheld from publication to avoid disclosing company proprietary data (table 1). CPC was the only domestic company that produced strontium carbonate from celestite; the company also produced strontium nitrate. All the celestite CPC used in 2000 was imported from Mexico; CPC owned and operated a second strontium carbonate plant in Reynosa, Tamaulipas, Mexico. The company used the black ash method of strontium carbonate production at both of its facilities.

The black ash and the soda ash methods are the two most common recovery techniques. The black ash method, known alternatively as the calcining method, produces chemical-grade strontium carbonate, which contains at least 98% strontium carbonate. The soda ash or direct conversion method produces technical-grade strontium carbonate, containing at least 97% strontium carbonate.

The first step in the black ash process involves mixing the crushed and screened celestite with powdered coal. The mixture is then heated to about 1,100° C, expelling oxygen in the form of carbon dioxide from the insoluble strontium sulfate to form water-soluble strontium sulfide. Strontium sulfide is dissolved in water, and the resulting solution is filtered. Then either carbon dioxide is passed through the solution or soda ash is added, forming and precipitating strontium carbonate from the solution. The precipitated strontium carbonate is filtered, dried, ground, and packaged. The byproduct sulfur from the process is recovered as elemental sulfur or other byproduct sulfur compounds (Chemical Products Synopsis, 1993). The black ash method is the preferred means of strontium carbonate production because it yields a higher grade product; most new production facilities employ black ash technology.

In the soda ash method, ground celestite is washed and most of the water removed. The thickened mixture is combined with soda ash and treated with steam for 1 to 3 hours. During this time, celestite and soda ash react to form strontium carbonate and sodium sulfate. Sodium sulfate is water soluble, making it possible to separate the insoluble strontium carbonate by centrifuging.

Several U.S. companies produced strontium compounds from strontium carbonate. Mallinkrodt Chemical Inc. of St. Louis, MO, and Laporte Pigments Corp. of Beltsville, MD, produced strontium chloride and strontium chromate, respectively. A few other companies produced downstream strontium compounds on a limited scale.

Consumption

The USGS estimated the distribution of strontium compounds by end use. Of the six operations to which a survey request was sent, five responded. The information collected from this survey and the information provided by the U.S. Census Bureau on strontium trade were the bases for the end-use estimates listed in table 2.

In 2000, more than 85% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and secondarily in ceramic ferrite magnets and other ceramic and glass applications. Since 1970, production of faceplate glass for color television picture tubes had been the major use of strontium.

All color televisions and other devices containing color cathode-ray tubes (CRTs) sold in the United States were required by law to contain strontium in the faceplate glass of the picture tube to block x-ray emissions. Major manufacturers of television picture tube glass incorporated, by weight, about 8% strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, it was converted to strontium oxide. In addition to blocking x rays, strontium improves the appearance of the glass and the quality of the picture and increases the brilliance (Wagner, 1986).

Permanent ceramic magnets were another large end use for strontium compounds in the form of strontium ferrite. These magnets were used extensively in small direct current motors for automobile windshield wipers, loudspeakers, other electronic equipment, toys, and magnetically attached decorative items. Strontium ferrite magnets have high coercive force and high thermal and electrical resistivities and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, do not react with most chemical solvents, and have a low density (Haberberger, 1971).

One of the most consistent and continuing applications for strontium was in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material was known to be better in this application. The compound used most frequently in these devices was strontium nitrate. Although strontium carbonate, strontium oxalate, strontium sulfate, and strontium chlorate could also be used, strontium nitrate was used in significantly larger quantities. Pyrotechnic devices were used in military and nonmilitary applications. Military pyrotechnic applications included tracer ammunition, military flares, and marine distress signals. Nonmilitary applications included warning devices and fireworks (Conkling, 1981).

Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid to the electrolyte reduces the lead content of the electrolyte and of the zinc deposited on the cathode (Bratt and Smith, 1963).

Strontium chromate also was used as an additive to corrosion-resistant paint to effectively coat aluminum most notably on aircraft fuselages and ships. These paints were used, to some degree, on aluminum packaging to prevent corrosion (Roskill Information Services Ltd., 1992, p. 76).

Strontium metal had a very limited part in total strontium consumption. Small amounts of strontium added to molten aluminum improve the castability of the metal, making it more suitable for casting items that had been made traditionally from steel. The addition of strontium to the melt improved the machinability of the casting. The use of cast aluminum parts had become common in the automotive industry because of the reduced weight and improved gas mileage achieved from the use of cast aluminum parts instead of steel (Lidman, 1984).

Other end uses consumed only small amounts of strontium and strontium compounds. As mentioned above, the presence of strontium in glass applications improves the brilliance of the glass. It also improves the quality of certain ceramic glazes, and eliminates the toxicity that may be present in glazes containing lead or barium. Strontium titanate was sometimes used as substrate material for semiconductors and in some optical and piezoelectric applications. Strontium chloride was used in toothpaste for temperature-sensitive teeth. For this application,

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impurities must be strictly controlled; some limits are in the parts-per-million range. Strontium phosphate was used in the manufacture of fluorescent lights, and the entire range of strontium chemicals was used in analytical chemistry laboratories.

Prices

Based on data published by the U.S. Census Bureau, the average customs value for celestite imported from Mexico was about $63 per ton, 12.5% lower than that of 1999. The average unit customs value of imported strontium carbonate was $0.56 per kilogram, slightly lower than in 1999. The corresponding value for strontium nitrate was $3.53 per kilogram, a decrease of about 9% from that of 1999.

Foreign Trade

Exports of strontium compounds were 52% higher than the levels reported in 1999 (table 3). This increase in exports was a result of increased strontium carbonate exports to Asia. In 1998, U.S. strontium carbonate exports to Asian countries were 24 t; in 1999 exports to Japan, Singapore, Taiwan, and Thailand totaled 3,500 t. The growth continued in 2000, with exports to Japan, the Republic of Korea, Singapore, and Taiwan totaling 5,680 t. This astounding increase was due to decreased production in Japan that resulted from plant closures in 1998 and high demand for strontium carbonate at television glass operations in Asia.

Imports of celestite from Mexico were 17,000 t, a decrease of nearly 46% from those of 1999. Although celestite import figures have varied significantly from year to year, the decease appeared to be attributable to a 2-year cycle of celestite imports. During the past 5 years, annual celestite imports averaged about 27,300 t (12,000 t contained strontium).

Mexico continued to be the most important source for imported strontium compounds, followed by Germany (table 4). Imports of strontium carbonate in 2000 were 12% higher than those of 1999. Imports from Mexico were 94% of total carbonate imports. Imports of strontium nitrate were 16% higher than those of 1999. Strontium nitrate imports have varied significantly from one year to the next but represented only about 1% of total strontium imports.

World Review

In most instances, celestite deposits occur in remote, undeveloped locations far from population centers in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly occurs along with barium and calcium, two elements with chemical properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy-intensive, strontium chemical producers require that material contain at least 90% strontium sulfate. Most operating celestite facilities can produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use gravity separation, froth flotation, or other methods to beneficiate ore.

The leading celestite producing countries were, in decreasing order of importance, Mexico, Spain, and Turkey. Significant quantities of celestite were produced in China and the former Soviet Union (FSU); not enough information was available, however, to make any estimates on location, number, or size of mines. Celestite was produced in smaller quantities in Argentina, Iran, and Pakistan.

Detailed information on most world resources was not readily available because very little information on exploration results had been published. Other deposits may well be identified but are in countries from which specific minerals information is not easily obtained (table 5). Production facilities for strontium compounds and metal were located in Canada, China, the FSU, Germany, Japan, the Republic of Korea, Mexico, Poland, and the United States.

Canada.—The world's leading producer of strontium metal, Timminco Ltd. produces strontium metal in Ontario. The company also produces strontium-aluminum master alloys, which were advertised as the highest quality in the world, referring to their purity, low gas content, fast dissolution rate, low porosity, precise weight, and highest and most consistent strontium recovery. Timminco sells strontium as crowns, sections, and turnings and in master alloys containing 90% strontium and 10% aluminum (Timminco Ltd., [undated], Strontium products, accessed May 25, 2001, at URL http://www.timminco.com/products/strontium.html).

Germany.—Solvay Barium Strontium GmbH, a subsidiary of Belgium's Solvay S.A., operates a 150,000-ton-per-year (t/yr) barium and strontium carbonate plant at Bad Hönningen. Solvay used imported Spanish celestite as the raw material for strontium carbonate production. The company has other strontium carbonate plants in Italy, the Republic of Korea, and Mexico (Industrial Minerals, 1999b).

Mexico.—With three strontium carbonate plants operated by CPC, Cia. Minera La Valenciana S.A. de C.V. (CMV), and Solvay Química y Minera, S.A. de C.V., Mexico was the world's largest producer of strontium carbonate. The vast majority of all U.S. strontium imports came from Mexico. CPC met its celestite requirements for its plants in Georgia and Mexico from mines that were completely controlled by CPC (Chemical Products Corp., [undated], Profile of Chemical Products Corporation, accessed May 25, 2001, at URL http://www.ceramics.com/cpc/cpc.html). CMV had proven and estimated reserves of 5 million metric tons, enough to continue production well into the future (Cia. Minera La Valenciana S.A. de C.V., [undated], Our future and our plans to remain the best, accessed May 25, 2001, at URL http://www.cmvlavalenciana.com.mx/our_future_and_plans_to_remain_the_best.htm).

Spain.—Two companies operated celestite mines in Spain, the last remaining celestite producing country in Europe. Solvay mined the Escuzar deposit to supply its German strontium carbonate operation. Canteras Industriales SL, a subsidiary of Bruno S.A., produced celestite from the Montevives deposit. Quimico Estroncio, a joint venture of Minas de Almadadén y Arrayanes, S.A., Fertiberia S.A., and Erkimia S.A., completed a new 22,000-t/yr strontium carbonate plant in Cartegena early in the year. The plant will produce strontium carbonate from Spanish celestite (Reguiro y Gonzáles-Barros and Sanz, 2000, p. 53-55). No production details from the new plant were available.

Turkey.—A long-time celestite producer for the export market, Barit Maden Turk AS sold most of its production to the

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Republic of Korea and China. The company was building its own strontium carbonate plant in 2000. In preparation for its expansion into carbonate production, Barit Maden built a carbon dioxide plant that was profitable for the company even before the strontium carbonate facilities were complete. Its high-quality celestite resources and the in-house carbon dioxide supply contributed to Barit Maden's confidence that its strontium carbonate would be high-quality and cost-competitive with other producers (Houssa, 1999, p. 47).

Outlook

Sales of televisions and computer monitors in the United States will continue at a high rate and will continue to influence U.S. strontium consumption significantly. Consumption for glass and ceramic applications for strontium carbonate is expected to grow at 3% to 5% per year for the near future (Industrial Minerals, 1999a). As long as CRTs are the preferred display type for televisions and computers, trends should remain steady with some small increases. Growth in television sales is expected to continue, and larger screens are increasing in popularity. Likewise, the market for personal computers is expanding, and the average size of monitors is increasing. These factors are driving increased demand for strontium carbonate for CRTs. Ferrite magnet markets are expected to be strong. Growth in other markets will probably continue at the current slower rate. Improved economic conditions worldwide will spur growth in demand for strontium carbonate.

Flat screen display systems for televisions and computer monitors have threatened to replace CRTs for many years, but low-cost technology has been elusive. Improvements have increased the likelihood that the large flat screens using either liquid crystal displays (LCDs) or plasma technology will replace bulkier CRTs. LCDs, which are smaller and use less energy than plasma display systems, seem to be filling the market for relatively small flat displays such as those required for portable computers. This market has experienced remarkable growth since 1997, and this trend is expected to continue. Plasma technology is more common for large, high-definition televisions with screens up to 60 inches wide. Significant growth is expected also in this area (Tremblay, 1999). Neither of these developing technologies requires strontium carbonate in the glass, but both are currently too expensive to make serious inroads in the domestic CRT market. The first common applications of flat screens should occur in Japan, where many homes are small and space is at a premium. A 20-inch flat screen television in Japan can cost around $2,500, significantly more than a comparable device with a CRT. Larger plasma screens (usually between 37 and 60 inches diagonally) cost between $10,000 and $14,000 (Landers, 2000).

Most of these devices were only available in Japan in 2000 but will eventually find acceptance in the United States, especially as the technology matures and prices go down. When these new display systems become more economically attractive to the general public, CRTs will become obsolete and so will the major market for strontium carbonate.

References Cited

Bratt, G.C., and Smith, W.N., 1963, The effects of strontium compounds and related materials in the electrolytic production of zinc, *in* Australian Conference on Electrochemistry, 1st, Sydney, New South Wales, Australia, 1963, Proceedings: New York, Pergamon Press, p. 939-948.

Chemical Products Synopsis, 1993, Strontium carbonate: Chemical Products Synopsis, Mannsville Chemical Products Corp., Cortland, NY, May, 2 p.

Conkling, J.A., 1981, Chemistry of fireworks: Chemical and Engineering News, v. 59, no. 26, June 29, p. 24-32.

Defense Logistics Agency, 1998, Solicitation of offers for celestite (strontium sulfate): Defense Logistics Agency, DLA-Celestite-001, June 17, p. 30.

Haberberger, T.H., 1971, Ferrite applications ever changing and expanding: Ceramic Industry Magazine, August, p. 29-32.

Hong, Wei, 1993, Celestite & strontianite—Review of ore processing and exploration: Industrial Minerals, no. 309, June, p. 55.

Houssa, Charles-Etienne, 1999, Talking Turkey—An update on the Turkish minerals industry: Industrial Minerals, no. 379, April, p. 21-47.

Industrial Minerals, 1999a, Mineral spotlight—Celestite: Industrial Minerals, no. 380, May, p. 23.

———1999b, Solvay increases $Ba/SrCO_3$ capacities: Industrial Minerals, no. 377, February, p. 23.

Landers, Peter, 2000, In Japan, the world goes flat: Wall Street Journal, June 29, p. B1, B4.

Lidman, W.G., 1984, Master alloys improve aluminum casting properties: Foundry Management and Technology, v. 112, no. 8, August, p. 46-47.

Reguiro y González-Barros, Manuel, and Sanz, Marchán, 2000, Industrial minerals of Spain—Europe's mining stronghold: Industrial Minerals, no. 394, July, p. 53-65.

Roskill Information Services Ltd., 1992, The economics of strontium 1992: Roskill Information Services Ltd., London, 93 p.

Tremblay, Jean-Francois, 1999, The skinny on flat-screen displays: Chemical & Engineering News, v. 77, no. 29, July 19, p. 19-28.

U.S. Department of Defense, 1960, National stockpile purchase specification: U.S. Department of Defense, P-10-R2, September 28, 1 p.

Wagner, R.G., 1986, Glass as a CRT fabrication material: Glass, v. 63, no. 6, June, p. 191-192.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Strontium. Ch. in Mineral Commodity Summaries, annual.
Strontium. Ch. in Minerals Yearbook, annual.

Other

American Ceramic Society Bulletin, monthly.
Chemical Market Reporter, weekly.
Engineering and Mining Journal, monthly.
Industrial Minerals (London), monthly.
Mining Annual Review (London).
Mining Engineering, monthly.
Mining Journal (London).
Mining Magazine (London).
Roskill Information Service Ltd. (London; last reported on strontium in 1992).
Strontium—Supply, Demand, and Technology. U.S. Bureau of Mines Information Circular 9213, 1989.
Strontium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
World Mining, monthly.

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TABLE 1
SALIENT STRONTIUM STATISTICS 1/

(Metric tons, of contained strontium, unless otherwise noted) 2/

	1996	1997	1998	1999	2000
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: 3/					
Strontium minerals	11,600	12,500	10,600	13,700	11,000
Strontium compounds	20,500	26,000	25,000	26,800	29,900
Exports (compounds) 3/	712	599	875	2,890	4,520
Shipments from Government stockpile excesses	--	--	--	--	--
Price, average value of mineral imports at port of exportation, dollars per ton	$67	$72	$60	$73	$62
World production (celestite) 4/	297,000 r/	265,000 r/	265,000 r/	323,000 r/	318,000 e/

e/ Estimated. r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits.

2/ The strontium content of celestite is 43.88%, which was used to convert units to celestite.

3/ Source: U.S. Census Bureau.

4/ Excludes China and the former Soviet Union.

TABLE 2
U.S. ESTIMATED DISTRIBUTION OF PRIMARY STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	1999	2000
Electrolytic production of zinc	2	2
Ferrite ceramic magnets	10	8
Pigments and fillers	3	2
Pyrotechnics and signals	6	9
Television picture tubes	75	77
Other	4	2
Total	100	100

TABLE 3
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1999		2000	
	Gross weight (kilograms)	Value 2/	Gross weight (kilograms)	Value 2/
Strontium carbonate precipitated:				
Australia	--	--	67,800	$175,000
Canada	254,000	$220,000	138,000	120,000
Germany	10,800	89,300	4,610	38,800
Japan	2,480,000	1,470,000	5,170,000	3,400,000
Korea, Republic of	--	--	82,000	92,700
Mexico	51,200	44,900	417,000	179,000
Singapore	577,000	342,000	307,000	164,000
South Africa	38,800	34,300	--	--
Taiwan	228,000	134,000	119,000	64,300
Thailand	213,000	129,000	--	--
United Kingdom	907	3,200	1,620	8,390
Venezuela	--	--	10,000	9,530
Total	3,860,000	2,470,000	6,320,000	4,250,000
Strontium oxide, hydroxide, peroxide:				
Australia	--	--	14,900	8,200
Brazil	124,000	48,300	26,700	14,700
Canada	272,000	150,000	432,000	238,000
Germany	19,600	9,500	99,200	47,100
Japan	176,000	96,900	74,000	40,700

See footnotes at end of table.

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TABLE 3--Continued
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1999		2000	
	Gross weight (kilograms)	Value 2/	Gross weight (kilograms)	Value 2/
Strontium oxide, hydroxide, peroxide--Continued:				
Korea, Republic of	82,800	51,000	161,000	88,300
Malasia	21,600	11,900	--	--
Mexico	127,000	85,500	--	--
Norway	20,100	11,100	44,200	24,300
Portugal	--	--	10,200	5,600
United Kingdom	10,600	5,840	--	--
Total	854,000	470,000	862,000	466,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1999		2000	
	Gross weight (kilograms)	Value 2/	Gross weight (kilograms)	Value 2/
Strontium carbonate:				
China	425,000	$191,000	270,000	$116,000
Germany	2,380,000	1,260,000	2,510,000	1,240,000
Italy	6,000	24,000	6,000	20,200
Japan	100	2,060	280	7,210
Mexico	41,100,000	24,200,000	46,500,000	26,200,000
United Kingdom	35	8,090	--	--
Total	44,000,000	25,700,000	49,300,000	27,600,000
Strontium metal:				
Canada	88,400	882,000	90,700	721,000
China	123,000	662,000	211,000	542,000
France	--	--	5,810	47,300
Germany	10	2,050	--	--
Japan	104,000	227,000	--	--
Mexico	--	--	281	2,690
Total	315,000	1,770,000	307,000	1,310,000
Strontium nitrate:				
China	195,000	256,000	234,000	254,000
Finland	--	--	57,700	137,000
France	174,000	1,150,000	209,000	1,190,000
Germany	--	--	150	6,020
Japan	98,700	771,000	107,000	698,000
Mexico	122,000	114,000	79,000	63,800
Switzerland	50	2,370	--	--
Total	590,000	2,290,000	687,000	2,350,000
Strontium oxide, hydroxide, peroxide:				
China	66,700	52,300	71,000	54,900
Germany	60,000	54,300	3,600	15,500
Japan	90,500	421,000	117,000	396,000
Mexico	30,300	57,300	--	--
Switzerland	20,000	15,600	--	--
Total	267,000	600,000	192,000	466,000

-- Zero.
1/ Data rounded to no more than three significant digits; may not add to totals shown.
2/ Customs value.

Source: U.S. Census Bureau.

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TABLE 5
CELESTITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Algeria e/	-- r/	-- r/	-- r/	-- r/	--
Argentina	3,775	3,049	3,100 e/	3,000 e/	3,000 4/
Iran e/ 5/	2,000 r/	2,000 r/	2,000 r/	1,650 r/ 4/	2,000
Mexico	143,892	134,707	118,230	164,682 r/	157,420 p/
Pakistan	2,500 e/	3,000 e/	598	634 r/	600
Spain e/	114,829 4/	92,000	111,000 r/	128,000 r/ 4/	130,000
Turkey e/	30,000	30,000	30,000	25,000	25,000
Total	297,000 r/	265,000 r/	265,000 r/	323,000 r/	318,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through May 18, 2001.

3/ In addition to the countries listed, China and the former Soviet Union produce strontium materials, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Data are for year beginning March 21 of that stated.

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SULFUR

By Joyce A. Ober

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

After nearly a century of world dominance in the production of native sulfur, the U.S. Frasch industry shuttered its last mine as a result of low sulfur prices, which were caused by weakened demand for phosphate processing, continually increasing competition from low-cost recovered sulfur producers, escalating production costs, and technical problems. Worldwide, production of native sulfur and pyrites continued to decline as environmental regulations forced increased sulfur recovery to limit atmospheric emissions of sulfur dioxide. Growth in sulfur recovery continued to outpace sulfur demand, resulting in increased stocks worldwide.

Through its major derivative, sulfuric acid, sulfur ranks as one of the more important elements used as an industrial raw material. It is of prime importance to every sector of the world's industrial and fertilizer complexes. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indices of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other chemical; 39.9 million metric tons (Mt), equivalent to about 13.1 Mt of elemental sulfur, were produced in 2000, slightly less than that in 1999 (U.S. Census Bureau, 2001).

Domestic production of sulfur in all forms was 9% lower; shipments, consumption, imports, and prices decreased (table 1; figures 1, 2). The United States maintained its position as the leading world producer and consumer of sulfur and sulfuric acid. The quantity of sulfur recovered during the refining of petroleum and the processing of natural gas continued the upward trend established in 1939. Sulfur produced by using the Frasch process was 50% lower than that of 1999 because of the closure of the last mine. Frasch production data were estimated by the U.S. Geological Survey (USGS) based on company reports and other public information. Production of recovered sulfur from petroleum refineries and natural gas processing operations was slightly higher than in 1999, although production from petroleum refining increased and natural-gas recovery remained about the same. Because shipments were higher than production, stocks decreased by 54%.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, produced as a result of laws restricting sulfur dioxide emissions, supplied a significant quantity of sulfuric acid to the domestic merchant (commercial) acid market. Production from this sector decreased by 22% because the three copper smelters that closed in 1999 were not reopened.

World sulfur production changed little in 2000 (table 1). Frasch production was lower because of continued production cutbacks in the United States. Elemental sulfur production from recovered sources, primarily during the processing of natural gas and petroleum products, increased slightly. Approximately 86% of the world's elemental sulfur production came from recovered sources; the quantity of sulfur supplied from these sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products, not for sulfur.

World sulfur consumption remained about the same with

Sulfur in the 20th Century

In 1900, Herman Frasch was trying to perfect his hot water melting process for producing sulfur. Domestic production was about 3,200 metric tons of sulfur valued at $88,100. Native sulfur deposits in Louisiana, Nevada, Texas, and Utah were mined with conventional mining methods. Domestic sulfur production, including mined elemental sulfur and pyrites, supplied about one-quarter of the U.S. sulfur demand of about 415,000 tons. Most sulfur and pyrites, domestic and imported, were used to produce sulfuric acid that was consumed in many different industries. Virtually all elemental sulfur imports came from the Italian island of Sicily, and pyrite imports were from unspecified locations. Pyrites remained a significant raw material for sulfuric acid until 1982. When the Frasch process was successfully commercialized in 1903, the U.S. sulfur industry took a turn for the better. By about 1915, the United States surpassed Italy as the world's leading producer of sulfur, a situation that continued throughout the century, during which eight companies produced nearly 340 million tons of sulfur from 36 mines in Louisiana and Texas. Frasch sulfur production hit its peak in 1974 when 12 mines produced 8 million tons.

Domestic production of elemental sulfur recovered as a byproduct of natural gas processing and oil refining was first reported in 1938 and grew steadily from that time. Recovered sulfur overtook Frasch as the primary domestic sulfur source in 1982. Sulfur also was recovered in the form of byproduct sulfuric acid from nonferrous metal smelters; production data were published for the first time in 1911.

In 2000, domestic sulfur production totaled 10.3 million tons, 81% from recovered operations, 9% from one Frasch mine, and 10% as byproduct acid from nonferrous metal smelters. Consumption was 12.5 million tons, including 2.8 million tons of imported sulfur and sulfur contained in sulfuric acid. The end uses did not change significantly during the century, although consumption in 2000 was nearly 4,000 times higher than it was in 1900. About 90% of domestic sulfur consumption was converted to sulfuric acid and then used, in decreasing order, in phosphate fertilizer and other agricultural chemical production, in oil refining, in copper ore leaching, and in many other industrial uses. Elemental sulfur was used as a plant nutrient, in synthetic rubber production, in pulp and paper products, and in other inorganic chemicals.

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about 50% used in fertilizer production and the remainder in myriad other industrial uses. World trade of elemental sulfur increased slightly from the levels recorded in 1999. Worldwide inventories of elemental sulfur were higher.

Legislation and Government Programs

The U.S. Environmental Protection Agency (EPA) issued the final rule for reduced sulfur content of gasoline early in 2000, as part of tier 2 of the Clean Air Act Amendments of 1990. The standards were nationwide standards, with the implementation time extended for some States and for some refining facilities. By 2006, the sulfur content in gasoline must average 30 parts per million (ppm) with an upper limit of 80 ppm. States in the Rocky Mountain region and Alaska were given until 2007 to reach standards, because those States generally had better air quality than other parts of the country. Small refineries with fewer than 1,500 employees or less than 155,000 barrels per day (bbl/d) of processing capacity were required to meet interim goals until 2008, when the national limits would be imposed. The 2008 deadline could be delayed until 2010 if the refiners could demonstrate a severe economic hardship. Small refineries received special consideration because the installation of new equipment in small facilities could be economically damaging (Oil & Gas Journal, 2000b).

The EPA began the process for new sulfur standards for diesel fuel by proposing new limits for sulfur, reducing the allowable content from 500 ppm to 15 ppm, a 97% decrease. The final rule was announced in December, although implementation of the new rule was delayed for further review. The EPA reduced diesel sulfur levels in a first step to clean up emissions from heavy-duty trucks and buses. In addition to reducing sulfur dioxide emissions from diesel engines, changes were made because new emission control apparatus needed to reduce particulate emissions from these vehicles could not operate effectively unless sulfur levels in the fuel were significantly reduced. The agency estimated the cost of diesel regulations at 4 to 5 cents per gallon (Oil & Gas Journal, 2001).

The petroleum refining industry was concerned, however, that the cost of compliance might be significantly higher than the EPA estimated, in the range of 15 to 50 cents per gallon. Costs that high could make it economically unfeasible for some facilities to install the necessary apparatus, forcing closure of refining capacity, and perhaps causing shortages in supply (Chemical Market Reporter, 2001). Low-sulfur diesel presented more technological challenges than low-sulfur gasoline, requiring more substantial investments for high-pressure hydrotreating facilities. The sulfur compounds found in diesel are more difficult to remove than those found in gasoline (Moyse, 2000). Refineries had several options for reducing sulfur levels to meet new regulations. The least expensive choice was using advanced catalysts in desulfurization units. Not all refineries would be able to use this alternative (Garritsen and others, 2000). Other more expensive treatment options for producing low-sulfur fuels were known (Moyse, 2000).

Other concerns about the new regulations addressed the issues of timing and transportation. Implementation of the new regulations was required on approximately the same time frame as those for gasoline. Questions were raised as to whether the refining industry would be able to make the required upgrades to diesel and gasoline facilities simultaneously without compromising the availability of either product. In addition, most diesel fuel is transported via pipelines that also transport home heating oil for which no new sulfur requirements were enacted. Industry officials believed that it would be difficult to prevent diesel product contamination from the pipelines that also carried the higher sulfur heating oil (Hess, 2000).

Production

Elemental Sulfur.—Production statistics were collected on a monthly basis and published in the USGS monthly sulfur Mineral Industry Surveys. All of the 120 operations to which survey requests were sent responded, representing 100% of the total production shown in table 1. In 2000, production was 7% lower than that of 1999. Shipments decreased by 3%, and the value of shipments was 35% lower owing to a decrease in the average unit value of elemental sulfur. Trends in sulfur production are shown in figure 2.

Frasch.—Native sulfur associated with the caprock of salt domes and in sedimentary deposits was mined by the Frasch hot-water method, in which the native sulfur was melted underground and brought to the surface by compressed air. Freeport-McMoRan Sulphur Inc., a subsidiary of McMoRan Exploration Co., was the last remaining Frasch producer in the United States. After announcing plans in July to close its Main Pass Mine by the end of the year, Freeport abruptly closed the mine 4 months early, at the end of August, citing low sulfur prices and increased operating expenses, especially natural gas prices, for the early closure (Fertilizer Markets, 2000c). An example of the scope of increased costs was the price of natural gas, a major constituent of Frasch production cost, which nearly doubled from the beginning of the year to July, with additional increases set for September (McMoRan Exploration Co., 2000b).

The mine also was closed ahead of schedule because a geologic and tectonic study revealed significant stability problems in a subsurface brine cavity. Continued production would have been impossible without substantial investment to remediate the problem. Because drilling activities had already been curtailed and mining was to be suspended at the end of the year, the company decided to close the mine rather than to incur the expense necessary alleviate the technical problems (Green Markets, 2000).

Main Pass was a mine operated on a salt dome sulfur deposit in the Gulf of Mexico, about 51 kilometers (km) (32 miles) from the coast of Louisiana. The Main Pass offshore complex, which was more than 1.6 km (1 mile) long and was the largest structure in the Gulf, had a production capacity of more than 5,500 metric tons per day (t/d) (McMoRan Exploration Co., 2000a). Production began in 1991 at a development cost of $880 million (Chemical & Engineering News, 2000).

When Freeport announced plans to close its mine, it proposed to concentrate on its sulfur transportation and marketing business and to continue meeting its supply contracts through purchases of recovered sulfur. The company later offered the sulfur logistics business for sale, expecting about $80 million for the deal. By yearend, a buyer had not been identified (Fertilizer Markets, 2001). In addition to the mine, Freeport's operations included facilities for forming, loading, remelting, and transporting sulfur in Galveston, TX; Port Sulphur, LA; and Tampa, FL.

Recovered.—Recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and

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coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered sulfur was produced by 39 companies at 117 plants in 26 States and 1 plant in the U.S. Virgin Islands. Most of these plants were small, with 33 reporting production exceeding 100,000 metric tons per year (t/yr). By source, 76% of recovered elemental sulfur production came from petroleum refineries or satellite plants treating refinery gases and coking plants. The remainder was produced at natural gas treatment plants. The largest recovered sulfur producers, in descending order of production, were Exxon Mobil Corp. (ExxonMobil), BP p.l.c., Chevron Corp., and Motiva Enterprises LLC. The 35 plants owned by these companies accounted for 50% of recovered sulfur output during the year. Recovered sulfur production by State and region is listed in tables 2 and 3.

Five of the 15 largest refineries in the world are in the United States. They are, listed by declining refining capacity, Hovensa LLC's St. Croix, U.S. Virgin Islands, refinery; ExxonMobil's Baytown, TX, and Baton Rouge, LA, refineries; and BP's Texas City, TX, and Whiting, IN, refineries (Chang, Thi, 2000), all of which were significant sulfur producing facilities. Refining capacity does not necessarily mean that these refineries are the largest producers of refinery sulfur. Sulfur production depends on installed sulfur recovery capacity, as well as the types of crude that are refined at the specific refineries. Large refineries that process low-sulfur crudes may have relatively low sulfur production.

Consolidation in the petroleum industry reduced the number of companies operating sulfur recovery operations, although the number of sulfur plants remained about the same. In 1998, Amoco Co. and British Petroleum Co., p.l.c., merged to form BP Amoco p.l.c. (BP Amoco p.l.c., 1999). On November 30, 1999, the U.S. Federal Trade Commission (FTC) approved the merger of Exxon Corp. and Mobil Corp. to form ExxonMobil (Chang, Joseph, 1999).

In April, the FTC approved the merger of BP Amoco p.l.c. with Atlantic Richfield Co. (ARCO). In order to receive approval, the companies agreed to sell all of ARCO's Alaska operations to Phillips Petroleum Co. The new company was called BP Amoco ARCO p.l.c., but the name was quickly simplified to BP p.l.c. (Oil & Gas Journal, 2000a).

Chevron Corp. and Texaco Inc. announced plans to merge to form ChevronTexaco Corp. The companies planned to merge in order to be better able to develop new oilfields and sources of energy (Hoffman, 2000). The new company will be the third largest oil and gas producer in the United States after ExxonMobil and BP. Some divestitures were likely to be required by the FTC before approval. Of particular interest were Texaco's refining and marketing joint ventures with Shell Oil Co. and Saudi Arabian Oil Co. (Westervelt, 2000). In response to the proposed merger of Chevron and Texaco, Shell considered buying Texaco's share of the Shell/Texaco alliances formed in 1997. This arrangement could eliminate many of the regulatory hurdles the Chevron/Texaco merger faced (PentaSul North America Sulphur Review, 2000a).

Mergers were becoming more common in the natural gas industry also. Duke Energy Corp. merged with Phillips Petroleum's gas gathering, processing, and marketing unit to form Duke Energy Field Services, LLC, owned 70% by Duke Energy and 30% by Phillips Petroleum (Duke Energy Corp., 2001, p. 12). El Paso Energy Corp. was in the process of acquiring The Coastal Corp. (North America Sulphur Service, 2000a). The El Paso Energy/Coastal merger was completed early in 2001, and the name was changed to El Paso Corp. (El Paso Energy Corp., 2001; El Paso Corp., 2001).

Several refining companies were in the process of upgrading their facilities to produce low sulfur fuels from higher sulfur crude oil. ExxonMobil was building a 40,000 bbl/d coker at its Baytown, TX, refinery in order to handle 530,000 bbl/d of Mexican sour crude from Petróleos Mexicano S.A. de C.V. (Pemex). The upgrades were designed to increase the quality of the fuels produced at Baytown. Sulfur production at the plant was likely to increase to between 350,000 to 360,000 t/yr from about 300,000 t/yr (North American Sulphur Service, 2000c). Marathon Ashland Petroleum LLC was upgrading and adding sulfur recovery capacity at its Garyville, LA, refineries to handle imports from Pemex (Cunningham, 1999b). The Premcor Refining Group Inc.—formerly Clark Refining & Marketing, Inc.—was upgrading its Port Arthur, TX, refinery to handle more heavy crude. New sulfur recovery capacity was being installed to increase production to more than 200,000 t/yr from 130,000 t/yr (North America Sulphur Service, 2000e).

Other companies were involved in joint ventures in which foreign sour crude producers contributed financing for the upgraded facilities. Phillips Petroleum and Petróleos de Venezuela, S.A. (PdVSA), completed installation of a new vacuum distillation unit and a coker at the Phillips Sweeny, TX, refinery to enable the facility to handle heavy crudes like those produced by PdVSA from the Venezuelan Orinoco Basin (Oil & Gas Journal, 2000c). Shell Oil Co. and Pemex were expanding their joint-venture Deer Park, TX, refinery to 340,000 bbl/d from 280,000 bbl/d. Maya crude will make up 65% of the throughput. Additional sulfur recovery capacity was to bring sulfur capacity to about 200,000 t/yr (North America Sulphur Service, 1999a).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters (table 4) accounted for about 10% of the total domestic production of sulfur in all forms, down from 12% in 1999. Four acid plants operated in conjunction with copper smelters, and six were accessories to lead, molybdenum, and zinc smelting and roasting operations. Even with the cutbacks at copper smelters, the four largest acid plants were all associated with copper mines and accounted for 81% of the output. The largest producers—ASARCO Incorprated, Kennecott Utah Copper Corp., and Phelps Dodge Corp.—operated a total of four copper smelters.

Byproduct acid decreased by 22% from that of 1999, because three of the seven copper smelters in the United States remained closed during the year. The 1999 closures resulted from a serious slump in the world copper industry, with adjusted copper prices lower than they had been at any time in the 20th century (McCoy, 1999).

Consumption

Apparent domestic consumption of sulfur in all forms was 7.0% lower than that of 1999 (table 5). Of the sulfur consumed, 77.6% was obtained from domestic sources, such as elemental sulfur (69.9%) and byproduct acid (7.7%), compared with 77.4% in 1999 and 79.2% in 1998. The remaining 22.4% was supplied by imports of recovered elemental sulfur (18.7%) and

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sulfuric acid (3.7%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification of industrial activities (tables 6, 7).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The largest sulfur end use, sulfuric acid, represented 77% of reported consumption with an identified end use. Some identified sulfur end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as "Unidentified." A significant portion of the sulfur in the "Unidentified" category may have been shipped to sulfuric acid producers or exported, although data to support such an assumption were not available.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed inorganic chemical, by volume. Based on USGS surveys, reported U.S. consumption of sulfur in sulfuric acid (100% basis) decreased by 7.5% and total sulfur consumption was 4.9% lower than that of 1999.

Agriculture was the largest sulfur-consuming industry, although it decreased to 8.6 Mt compared with 9.2 Mt in 1999. Reported consumption in phosphatic fertilizers was 8.5% lower than that of 1999, a result of decreased production of phosphoric acid. Based on export data from the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by 16% to 4.8 Mt.

The second largest end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported a slight increase in the consumption of sulfur in that end use. Because oil refineries had operated near capacity in 1999 and 2000, little change was expected.

Demand for sulfuric acid in copper ore leaching, the third largest end use, decreased by 7.6%. This use of sulfuric acid decreased for the second consecutive year as a result of downturns in the copper industry. Planned expansions at copper leach operations, however, were expected to cause increased consumption for this use by 2001. All copper producers, even companies that closed smelter operations, continued to operate their solvent extraction-electrowinning (SX-EW) operations in which weak sulfuric acid dissolves copper as it percolates through specially prepared beds of copper minerals. The copper is then concentrated through a solvent extraction process, and the concentrated solution undergoes an electrowinning process that produces 99.99% copper cathode (Phelps Dodge Corp., 1999).

Phelps Dodge was converting its Morenci, AZ, site to the SX-EW process. Upon completion, the 45% increase in SX-EW capacity should require a comparable increase in sulfuric acid consumption for the process. The company's copper smelter near Chino, NM, initially was expected to supply a portion of the necessary acid with the remainder being purchased (Sulfuric Acid Today, 1999). The decreased byproduct acid production resulting from the closed smelters and the expansion of solvent extraction operations in the same area presented the potential for reduced acid supplies for the new SX-EW capacity. Phelps Dodge was considering the option of installing a sulfur burner at its shuttered Hidalgo, NM, sulfuric acid plant. The company would be able to meet its requirements for its leach operations with virgin acid from Hidalgo (North America Sulphur Service, 2000b). Poorer than expected financial results for the company in the first half of 2000 delayed action on the sulfur burner plan (North America Sulphur Service, 2000d). A new solvent extraction copper operation was planned for development in Utah that would use byproduct sulfuric acid produced at Kennecott Utah Copper's smelter (Sulphur, 2000a).

The U.S. Census Bureau reported 5.73 Mt of sulfuric acid was produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes (U.S. Census Bureau, 2001). This material was recycled by companies that produced acid for consumption in their own operations and also recycled acid used in their plants. The petroleum refining industry was believed to be the largest source and consumer of recycled acid for use in its alkylation process.

Stocks

Yearend inventories held by Frasch and recovered elemental sulfur producers decreased to 208,000 metric tons (t), about 54% less than those of 1999 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 6-day supply, compared with a 12-day supply in 1999, a 7-day supply in 1998, a 20-day supply in 1997, and a 17-day supply in 1996. Yearend stocks were lower than they had been since Frasch production became profitable early in the 20th century (Haynes, 1959, p. 61). Final stocks represent 4% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1978, p. 1296). In October, Freeport shipped nearly all the sulfur it had in stocks as it was attempting to exit the sulfur business. In most cases, it was difficult for recovered sulfur producers to accumulate any significant stockpiles. Many recovered operations did not have sufficient space for storing excess sulfur, and in many locations, environmental regulations did not allow stockpiling to occur. Without Frasch production, domestic sulfur stocks were expected to remain relatively stable.

Prices

The contract prices for elemental sulfur, at terminals in Tampa, FL, reported weekly in Green Markets, began the year at $61 to $64 per metric ton. Prices quickly decreased to between $56 to $59 per ton and remained steady until the end of October, when they increased to between $62 to $66 per ton, where they remained throughout the rest of the year.

Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was $24.73 per ton, which was 35% lower than that of 1999. Prices varied greatly on a regional basis, causing the discrepancies between Green Markets prices and USGS prices. Tampa prices were usually the highest prices reported because of the large sulfur demand in the central Florida area. U.S. West Coast prices were $0 to $1 per ton, though, in reality, West Coast producers often faced negative values as a result of costs incurred at forming plants. These costs were necessary to make solid sulfur in acceptable forms, often known as prills, to be shipped overseas. The majority of West Coast sulfur was sent to prillers

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who may have been subsidized by the refineries, and the formed sulfur was shipped overseas (Green Markets, 1999c).

Foreign Trade

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, were 11% higher in quantity than those of 1999 and 50% higher in value, as listed in table 8, because the average unit value of U.S. export material increased. The average unit value of exported elemental sulfur increased to $70 per ton from $52 per ton, which was 35% higher than in 1999. Exports from the West Coast were 659,000 t, or 86% of total U.S. exports.

The United States continued to be a net importer of sulfur—imports of elemental sulfur exceeded exports by 1.6 Mt. Recovered elemental sulfur from Canada and Mexico delivered to U.S. terminals and consumers in the liquid phase furnished about 94% of all U.S. sulfur import requirements. Total elemental sulfur imports decreased by about 10% in quantity and decreased by 24% in value; imports from Canada, mostly by rail, were 3% higher; and waterborne shipments from Mexico were 10% lower than those of 1999 (table 10). Imports from Venezuela were estimated to account for about 6% of all imported sulfur.

The most unusual detail concerning imports was that one shipment of about 46,000 t of formed Canadian sulfur was transported by ship from Vancouver, British Colombia, to Galveston, TX. Because the closure of Main Pass raised questions about possible sulfur supply shortages by yearend, Freeport imported one shipload of solid sulfur from Canada. Unlike most Canadian imports that entered the United States as molten sulfur by rail into the northern States and went cross-country to Florida, Freeport's shipment was transported by ship from Vancouver to Galveston, where Freeport operated remelting facilities. Freeport also bought formed sulfur from Hovensa LLC in St. Croix, U.S. Virgin Islands, for remelting to meet their supply contracts (PentaSul North America Sulphur Review, 2000b).

With the decreased supplies and some concern of price increases at yearend, several Florida fertilizer companies were pursuing necessary permits to build a terminal south of Tampa to handle formed sulfur. After several unexpected delays late in 2000, Big Bend Transfer Station Co. (BBTC) received from the Hillsborough County Commission approval for its sulfur melting plant south of Tampa early in 2001. The joint venture formed by Cargill Inc.; CF Industries, Inc.; and IMC Global Inc. planned to build a facility for remelting formed sulfur as a means of diversifying their supply options. The project needed an air quality permit from the county's Environmental Protection Commission. Upon successful completion of the permitting process, BBTC planned to install facilities for handling 1.5 million tons per year (Mt/yr) of sulfur, with possible expansions to 2 Mt/yr (Green Markets, 2001). This would enable BBTC to buy formed sulfur at the best prices available, perhaps from foreign producers.

In addition to elemental sulfur, the United States also had significant trade in sulfuric acid. Sulfuric acid exports were 23% higher than those of 1999 (table 9). Acid imports were more than seven times greater than exports (tables 9, 11). Canada was the source of 57% of U.S. acid imports, most of which were probably byproduct acid from smelters. Canadian shipments to the United States came by rail, and the remainder of imports came primarily by ship from Europe, Latin America, and Japan. The tonnage of imports of sulfuric acid was 3.5% more than that of 1999, but the value of imported sulfuric acid decreased by 34%.

World Review

The global sulfur industry remained divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of native sulfur or pyrites is based on the orderly mining of discrete deposits, with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct, the quantity of output subject to demand for the primary product irrespective of sulfur demand. Nondiscretionary sources represented nearly 87% of the sulfur in all forms produced worldwide as listed in table 12.

With the termination of Frasch production in the United States, Poland was the only country that produced more than 1 Mt of native sulfur by using either the Frasch or conventional mining methods (table 12). Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China was the only country in the top 15 sulfur producers whose primary sulfur source was pyrites. About 71% of all pyrites production was in this country.

Of the 25 countries listed in table 12 that produced 400,000 t or more of sulfur, 18 obtained the majority of their production as recovered elemental sulfur. These 25 countries produced 94% of the total sulfur produced worldwide. The international sulfur trade was dominated by a limited number of exporting countries, which, in descending order of importance, were Canada, Russia, Saudi Arabia, Japan, and the United Arab Emirates; these countries exported more than 1 Mt of elemental sulfur each and accounted for 64% of total sulfur trade. Major sulfur importers, in descending order, were China, Morocco, the United States, India, Tunisia, and Brazil, all with imports of more than 1 Mt.

World production of sulfur was virtually the same in 2000 as it was in 1999; consumption was believed to be slightly higher. Statistics compiled by CRU International Ltd. showed 1998 to be the seventh consecutive year in which sulfur supplies exceeded demand. Although complete data for 1999 and 2000 were not available, it could be assumed that 2000 represented the ninth consecutive year of excess sulfur supplies (Kitto, 2000).

Prices in most of the world were believed to have averaged higher throughout the year, but with a slight decrease at yearend. Production of native sulfur was 20% lower than that of 1999 as a result of termination of mining in the United States. Frasch production in Poland increased by 17%, the first increase there since 1995. Recovered sulfur production increased slightly and byproduct sulfuric acid production decreased by about 4% from those of 1999. Supply continued to exceed demand; worldwide sulfur inventories increased, much of which was stockpiled in Canada. Globally, sulfur from pyrites decreased by 13%, much of which was a result of the continued decline in China and the conversion of a pyrite-based sulfuric acid plant in Spain to a sulfur burner.

Statistics compiled by the Oil & Gas Journal showed the

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United States producing 20% of the world's total refining capacity and 42% of the world's sulfur recovery capacity derived from oil refineries. The publication listed 742 oil refineries in 114 countries; only 54 of these countries were reported to have sulfur recovery capacity (Stell, 2000, p. 67-68). Although the sulfur recovery data appeared to be incomplete, analysis of the data showed that most of the countries reporting no sulfur recovery at refineries were small, with developing economies and limited refining industries. In general, as refining economies improve and the refining industries mature, additional efforts are made to improve sulfur recovery and atmospheric emissions.

Mergers of major oil producers were not limited to the United States. Following the merger in 1999 of France's Total and Belgium's Compagnie Financère Belge des Pétroles (PetroFina) to form TotalFina, the new company merged with Société Nationale Elf Aquitaine to form Total Fina Elf S.A. (TotalFinaElf). The deal formed the world's fourth largest oil company. For approval by the European Commission, TotalFina was required to divest some of its assets in France. TotalFinaElf owned 55% of France's refining capacity (Chemical Market Reporter, 2000a).

Regulations were enacted in many countries limiting the amount of sulfur allowable in fuels and the quantity of sulfur dioxide emitted into the atmosphere. Many of these regulations will result in increased sulfur recovery. Bulgaria, Canada, China, the European Union (EU), Thailand, and the United States set or proposed significant, although varied, reductions in the sulfur content of motor fuels sold in those countries. Suppliers were required to met these new standards by between 2005 and 2011. Germany, already covered under EU regulations, accelerated the timetable for new EU guidelines to be met in Germany to 2001 and was pushing for more stringent limitations in the EU's next round of rulemaking (Sulphur, 1999d). Based on Germany's urgings, European oil industry experts expected sulfur in gasoline to be reduced to 10 ppm by 2003. Germany was suggesting sulfur-free fuels throughout the European Union by 2007 (Cunningham, 2000b, p. 14). The Japanese auto industry proposed further cuts to the sulfur level of motor fuels in Japan. Allowable sulfur in gasoline was 100 ppm with reduction to 50 ppm set for 2005. The new proposal suggested limiting sulfur to 5 to 10 ppm. No timeframe for implementation was established (Sulphur, 2000k). At the 2000 European Oil Refining Conference, discussions addressed additional legislation to further limit sulfur in fuels. Legislation enacted in 1999, which would take effect in 2000, reduced the allowable sulfur in nonmotor heavy fuel oils to 1% (Cunningham, 2000b, p. 13).

European refineries faced challenges in upgrading to meet new fuel specifications. Premium prices charged for cleaner fuels were not expected to make up for the poorer yields and higher processing costs resulting from deeper desulfurization. Upgrading a typical refinery in Europe was estimated to cost more than $100 million (Packer, 2000). Total cost estimates of new European fuel specifications, including reduced sulfur content, could approach $9 billion. Increased costs would include expenditures needed for installing new facilities; modifying existing plants; increased operating expenses; new maintenance, insurance, and overhead charges; and storage fees for seasonal products (Richardson and du Preez, 2000). A European petroleum industry expert estimated that the total worldwide cost of producing low-sulfur motor fuels could approach $2.5 trillion (Sulphur, 2001).

The next targets for this type of legislation were expected to be marine bunker fuels, fuels used by ocean going vessels. The International Maritime Organization—the international governing organization for shipping—had set a 4.5% sulfur specification for these heavy fuel oils. The average sulfur content of bunker fuels was considerably less at about 3%; but even at that level, the emissions from bunker fuel were around 4 Mt/yr of sulfur in sulfur dioxide. The European Union was considering the imposition of more stringent sulfur restrictions on fuels used in ships traveling in the English Channel, the Baltic Sea, and the North Sea because shipping has become the source of an increasingly large portion of sulfur dioxide emissions in Europe. From 1990 to 2000, the shipping portion of European sulfur dioxide emissions increased from 10% to 30%. The major factor contributing to this increase was that emissions from motor vehicles had decreased. Negotiations for establishing worldwide marine fuel requirements were expected to be contentious and time-consuming. Local restrictions were likely to be imposed prior to international agreements being reached. After bunker fuels were addressed, more controversy was expected when the sulfur content of jet fuel was debated (Sulphur, 2001b). The U.S. Air Force and the U.S. Department of Energy were assessing the reduction of the sulfur content of jet fuels as a first step toward decreasing sulfur dioxide emissions from advanced propulsion systems. The research was aimed at understanding how sulfur compounds in jet fuels affect engines and emission control systems before mandating reduced sulfur levels in jet fuels (Sulphur, 2000e).

In many countries, companies were installing additional capacity for recovering sulfur and byproduct sulfuric acid, as well as producing low-sulfur fuels in advance of new government mandates and/or before legal requirements of existing laws took effect. Firms in Canada, Egypt, Germany, the Netherlands, Russia, the United Arab Emirates, the United States, and Uzbekistan were reducing sulfur dioxide emissions at their facilities. Low-sulfur fuels were offered years in advance of legal requirements in Bahrain, Kuwait, the United Kingdom, and the United States.

Not all of these developments caused significant increased production, but most created at least incremental additions to sulfur supplies. These increases in sulfur recovery, coupled with the widespread trend toward higher sulfur content in crude oils, promised continued growth in worldwide production of recovered sulfur and byproduct sulfuric acid. Only discretionary sulfur production was expected to decrease.

Australia.—Technical problems seemed to be resolved for most of Australia's nickel laterite projects using a pressure acid leach process (PAL). The PAL represented a potential demand for large quantities of sulfur to produce the sulfuric acid needed for the process. In PAL operations, nickel laterite ore slurries were leached with sulfuric acid at up to 250° C, in a titanium clad autoclave. Sulfuric acid consumption could be up to 30 t of acid per ton of metal produced—enough to justify the installation of a sulfur-burning sulfuric acid plant (Sulphur, 2000i).

QNI Pty. Ltd. and Comet Resources Ltd. planned a PAL project in Western Australia (QNI Pty. Ltd., 2000). Anaconda Nickel Ltd. was working on three PAL projects. The Murrin Murrin project achieved design capacity during the year and proceeded with its second stage of development. The company's Mount Margaret project was under development and

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expected to quickly achieve design capacity taking advantage of the lessons learned at Murrin Murrin. Mount Margaret was to begin construction early in 2001, with commissioning and production beginning in 2003. A third operation, Cawse, was planned to begin in 2004 (Cunningham, 2000a).

The world's largest single-stage sulfuric acid plant provided all the acid required for stage I at Murrin Murrin. Additional acid would be required from another acid plant or byproduct acid from local sources to meet requirements for stage II. Sulfuric acid plants were planned for the other projects (Cunningham, 2000a).

Estimates placed the sulfur requirements for each planned acid plant at between 500,000 to 750,000 t/yr of sulfur. Total requirements for the Anaconda projects were expected be between 2.5 to 3 Mt/yr of elemental sulfur within 5 years. Anaconda was considering the development of a phosphate fertilizer project in the same region to make better use of the infrastructure built to support the nickel projects. The phosphate project would require an additional 400,000 to 500,000 t/yr of sulfur. Canada has provided much of the sulfur for the new Australian demand, but diversified markets were being pursued, with Middle Eastern sulfur likely offering competition for Canadian suppliers (Cunningham, 2000a).

Bahrain.—Bahrain Petroleum Co. planned to update its refinery to produce diesel fuel containing between 50 to 500 ppm sulfur. Hydrogen cracking would reduce sulfur from 7,500 ppm. Bahrain processed crude oils from its own oilfields, from off-shore operations shared with Saudi Arabia, and from Saudi Arabian crudes (Sulphur, 2001c).

Canada.—Second only to the United States in sulfur production in all forms, Canada led the world in the production of byproduct sulfur, exports of elemental sulfur, and stockpiled material. The majority of the sulfur production came from natural gas plants in Alberta where sulfur inventories reached 13.2 Mt (PentaSul North America Sulphur Review, 2001).

In addition to the large reserves of high-sulfur natural gas, Alberta has huge deposits of oil sands with estimated reserves of 300 million barrels of recoverable crude oil that also contain 4% to 5% sulfur (Stevens, 1998). As traditional petroleum production in Canada declined, oil sands were becoming a more important source of petroleum for the North American market (Cunningham, 2001) The Athabasca oil sands were a mixture of sand, water, clay, and bitumen, a naturally occurring viscous mixture of heavy hydrocarbons. Because of its complexity, bitumen was difficult or impossible to refine at most oil refineries. It was upgraded to a light-oil equivalent before further refining or was processed at facilities specifically designed for processing bitumen. Oil sands with more than 10% bitumen were considered rich; those with less than 7% bitumen were not economically attractive (Oil & Gas Journal, 1999).

Shallow deposits were amenable to strip mining, but deeper deposits required in situ technology whereby the bitumen was separated underground from the matrix that contained it with steam injection. Bitumen was separated from the oil sands matrix by mixing it with heated water. With in situ operations, steam assisted gravity drainage flushed the hydrocarbon out of the matrix, forming a pool that was pumped from the ground and transported to an upgrader via pipeline. During upgrading, the very large hydrocarbon molecules were reduced, creating molecules that are more easily processed. Furnace treatment produced petroleum coke that was used in other industries. Hydrogen addition or hydrogen conversion inserted additional hydrogen atoms into the bitumen molecules and, in the process, broke them down into smaller compounds and removed much of the sulfur. The simplified hydrocarbon, known as synthetic crude oil, was then processed at traditional refineries (Cunningham, 2001).

Three surface operations were in production or under development in Alberta and at about 75 in situ projects. Surface minable reserves were estimated to be 33 billion barrels (Gbbl) with less than 9.9 Gbbl under development. Estimates for reserves appropriate for in situ processes were 142 Gbbl. Production of sulfur from oil sands could approach 2 Mt/yr by 2015 based on projections for oil sands production. Where the sulfur was actually produced depended on the type of upgrader chosen. If a coker was installed, the sulfur could be contained in the petroleum coke product and recovered at the location where the coke was consumed. If hydrocracking was used, then the sulfur was recovered on site (Cunningham, 2001).

Syncrude Canada Ltd. began production at its Aurora Mine in August. The company's second oil sands mine, about 35 km from its existing operation near Fort McMurray, Alberta, was the first such operation to be remote from most necessary processing facilities. Syncrude used newly developed technology that allowed partial processing of the mine output before transporting bitumen froth by pipeline to the company's Mildred Lake operation for further upgrading. Syncrude used a its newly developed low energy extraction process that removed the bitumen from the sand at much lower temperatures than that required by more tradition processing techniques, cutting energy consumption by about 40% (Syncrude Canada Ltd., 2000). The company stored the sulfur recovered at the upgrading facility (Syncrude Canada Ltd., [undated], Sulphur and nitrogen removal, accessed June 27, 2001, via URL http://www.syncrude.com). Logistical problems at Fort McMurray made it difficult and costly to get the sulfur produced to market. Rail lines did not connect to the plant site, necessitating the trucking of sulfur through the town to reach the railhead (North America Sulphur Service, 2000c). Syncrude provided space for Alberta Sulphur Research Ltd. to test its underground sulfur storage method. The sulfur stocks to be tested were buried in 1999, with several years of environmental evaluation planned (Sulphur, 1999c).

Albian Sands Energy Inc., a joint venture of Shell Canada Ltd. (60%), Chevron Canada Resources Ltd. (20%), and Western Oil Sands Inc. (20%), began construction on all aspects of its Can$ 3.5 billion oil sands project in northern Alberta. The project included the Can$1.8 million Muskeg River Mine, 75 km north of Fort McMurray; the Can$1.7 million upgrade at Shell Canada's Scotford refinery near Fort Saskatchewan, Alberta; and Corridor Pipeline Ltd.'s 450-km dual pipeline system to carry diluted bitumen from the mine to Scotford and transport diluent to the mine. The pipeline project included a 43-km pipeline to carry feedstock from other operations to the upgrader and deliver upgraded material to the refinery and terminals near Edmonton, Alberta (Oil & Gas Journal, 2000d). The construction was proceeding on schedule with production expected to begin by the end of 2002 (Albian Sands Energy Inc., 2000). Albian Sands' plans included production of 500,000 t/yr of molten sulfur that would be recovered at the Scotford Refinery (North American Sulphur Service, 1999b).

Koch Industries, Inc.'s, TrueNorth Energy L.P. subsidiary expanded its Fort Hill oil sands project leases to bring the total

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minable reserves at the operation to 2.4 Gbbl. TrueNorth expected to begin producing 95,000 bbl/d of bitumen by 2005. Production at the site could continue at that rate for 60 years. No upgrade was planned for the project (Sulphur, 2001f). Petro-Canada was considering the construction of a bitumen upgrade at its Edmonton, Alberta, refinery to handle production from its McKay River oil sands project near Fort McMurray. The refinery processed synthetic crude at Syncrude Canada Ltd.'s plant at Fort McMurray (Sulphur, 2000o).

Irving Oil Ltd. was spending Can$1 billion to upgrade its Saint John, New Brunswick, refinery to meet Canada's gasoline sulfur specifications that go into effect in 2005. The upgrade was to reduce sulfur dioxide emissions at the refinery and improve the reliability of environmental controls. Reductions in atmospheric sulfur dioxide emissions were self-imposed. The refinery already met New Brunswick and Canadian regulations (Goodwin, 2000).

Chile.—Corporación Nacional Del Cobre (Codelco) and Finland's Outokumpu Oyj agreed to work together to develop new flash smelting technology to modify Codelco's Chuquicamata smelter. The upgrade at the smelter would significantly decrease sulfur dioxide emissions (Outokumpu Oyj, 2000). Outokumpu also was considering the construction of a copper smelter in Mejillones. Upon completion sometime after 2003, the smelter would have the capacity to produce 350,000 t/yr of copper and 1 Mt/yr of sulfuric acid (Sulphur, 2000c).

Noranda Inc. of Canada was expanding its Altonorte smelter to increase copper production by about 80%. Sulfuric acid production capacity, however, will nearly triple to 700,000 t/yr. The upgrade would make Altonorte more cost competitive and enable the company to capture 90% of the sulfur dioxide released by the smelter. The complete modernization project was expected to be completed in 2003 (Sulphur, 2000n).

China.—One of the few countries whose primary domestic source of sulfur was pyrites, China was working to convert much of its sulfuric acid capacity from pyrites burning to elemental sulfur. Some new elemental sulfur-based acid plants were built, but much of the conversion was through adapting existing pyrites operations to use solid sulfur. The conversions were driven by economic and environmental reasons (Fertilizer Markets, 1999). Environmental awareness was a relatively recent concern in official Government considerations. Pyrite-based sulfuric acid plants in China emitted sulfur dioxide and other pollutants to the atmosphere, discharged pollutants to rivers and contaminated groundwater, and presented solid waste disposal problems. A properly operated sulfur-burner has very limited atmospheric emissions, no water discharge, and no solid waste issues (Sears, 2000).

The Chinese pyrite industry faced additional setbacks when Nanjing Chemical Industry Group, a leading producer of sulfuric acid, announced plans to switch to elemental sulfur burning. The reconstructed plant was to use sulfur recovered from Chinese oil refineries (Sulphur, 2001i). The China Sulphuric Acid Industry Association forecast sulfuric acid production to grow to 28 Mt in 2005 from 23 Mt in 2000, representing an increased sulfur demand of about 1.7 Mt (Sears, 2000).

The Chinese petroleum industry was working to modernize its facilities to reduce sulfur emissions as it increased imports of sour crudes from the Middle East (Sulphur, 2001i). Chinese imports of crude oil have been sweet crudes because of the country's inadequate sulfur recovery capabilities. Work was progressing to improve sulfur recovery units at several refineries. Additional improvements at smelters were expected to increase availability of byproduct acid (Sears, 2000)

Chinese crude petroleum was relatively sweet with little sulfur recovered at refineries. In fact, only 1 of China's 95 refineries had any sulfur recovery capacity, amounting to just more than 100,000 t/yr. Restructuring of the refining industry included plans for large-scale increases in sulfur recovery capacity. Joint ventures with major oil producers willing to make investments in the Chinese industry were a large part of the strategy for reducing imports of oil products and improving the refining technology (Cunningham, 1999a).

Germany.—As one of the largest sulfur producing countries in Europe, discrepancies existed between official Government production statistics and other sources reporting German production. Other sources showed German production significantly higher than Government sources, with nearly 1 Mt more production of sulfur in all forms than official data. Most German sulfur was sold in European Union markets. Although official U.S. Census Bureau statistics suppressed data regarding United States imports from Germany, the United States was believed to have received sulfur shipments from Germany (Fertilizer Focus, 2001).

Norddeutsche Affinerie AG completed the expansion of its Hamburg copper smelter in November. The upgrade raised the sulfuric acid capacity of the smelter to 1.3 Mt. Production was targeted toward the northwestern European markets (Fertilizer Week, 2000). Norddeutsche Affinerie was considering a further 50% expansion of its copper and sulfuric acid capacity. The expansion would bring the company's total sulfuric acid capacity to nearly 2 Mt/yr. A location for the new operation was not identified (Sulphur, 2001h).

Iran.—Major oil companies were showing increased interest in exploration in Iran. A refinery with sulfur recovery capacity was completed in Iran's Hormuzgan Province. A new gas processing plant to process natural gas from the South Pars gasfield was under construction. The sulfur recovery at the gas plant was expected to be 400 t/d. Eight phases of development were planned for the South Pars field. When development was complete, sulfur output from the field could reach 500,000 t/yr (Cunningham, 2000d) Sulfur producers in Iran were installing forming capacity to improve their competitiveness with other major sulfur exporters (Sulphur, 2000f).

Iraq.—Questions remain about Frasch and other sulfur production in Iraq. Before Iraq invaded Kuwait precipitating Operation Desert Shield in 1990 and Operation Desert Storm (the gulf war) in 1991, Frasch production at the Mishraq Mine was around 1 Mt/yr, with plans to expand capacity to 2 Mt/yr. Some recovered sulfur was also produced in Iraq. Since that time, with the imposition of economic sanctions by the United Nations (UN) and very limited public information of any kind coming from Iraq, little was known of sulfur production in that country. Mishraq was not believed to be damaged during the war and could be operating at or near capacity, although that scenario is doubtful. The most likely situation was that Mishraq produced consistently since 1990 but at a greatly reduced rate. Recovered sulfur production probably continued. With little outlet for any products as a result of the sanctions, significant stocks of sulfur were believed to have accumulated at Mishraq since the imposition of sanctions. Sulfur also was produced at two sour gas processing plants at Kirkuk and Beiji (Fertilizer

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Markets, 2000b).

Iraq reached an agreement with Jordan to supply all of Jordan's sulfur requirements starting in late 2000 and through 2001. UN sanctions against Iraq ban most trade with Iraq since Iraq invaded Kuwait in 1990. Jordan invoked an article of the UN charter that allows a UN member state not to implement a sanction if it is against that country's domestic interests. The price of the Iraqi sulfur, probably from the Mishraq Frasch Mine, was estimated to be nearly one-third less than similar material from elsewhere in the Middle East (Sulphur, 2000g). Jordan received 150,000 t of sulfur from Iraq in 2000 with up to 1 Mt expected in 2001 (Fertilizer Markets, 2000b).

Kazakhstan.—The Tengiz oilfield with associated gas on the northeast shore of the Caspian Sea in western Kazakhstan has been operated by Tengizchevroil (TCO) since 1993. In 2000, Chevron Corp. raised its stake in TCO to 50%. Other owners in TCO were Kazakhoil (the Republic of Kazakhstan's national oil and gas company with 20%), ExxonMobil (25%), and LUKARCO (a joint venture between BP and Russian oil company LUKoil with 5%) (Chevron Corp., 2000a). One of the world's largest oilfields, Tengiz contains high-quality oil with 0.49% sulfur and associated natural gas that contains 12.5% hydrogen sulfide (Connell and others, 2000).

In 2000, TCO completed an oil and gas expansion project that included additional sulfur production capacity and further expansions were planned (Chevron Corp., 2000a). TCO was studying the feasibility of reinjecting sour gas into the Tengiz reservoir and reducing the quantity of sulfur recovered at the site (Chevron, 2000b, p. 23). Sulfur production at Tengiz was around 1.3 Mt in 2000 with likely expansion to 2 Mt by 2005 and the potential to reach 3.8 Mt by 2010 (Cunningham, 2000e).

Mexico.—A former Frasch producer from 1954 when mining began at San Cristobal (Larson and Marks, 1955, p. 1136-1137) until 1993 when the Texistepec Mine closed (Ober, 1994, p. 1172), Mexico was the second largest supplier of imported recovered sulfur to the United States. Mexico recovered most of its sulfur from its petroleum refineries and recovered byproduct sulfuric acid at its smelters.

Mexican crude oil was classified in four specific types. With production of 1.5 million barrels per day, maya crude was the type with highest production and lowest quality. Maya crude was heavy, making it difficult to refine at conventional refineries, and had an average sulfur content of 3.4%. Second in production at 950,000 bbl/d, isthmus crude had medium weight and sulfur content of about 1.4%. Marine light contained 1.23% sulfur and production was 721,000 bbl/d. Olmeca, the highest quality Mexican crude with 0.93% sulfur, had the lowest production at 455,000 bbl/d. Pemex refineries processed about 45% of domestically produced crude oil. The remainder was exported; primary customers, in descending order, were the United States, Spain, the Netherlands Antilles, and Japan (Manriquez and others, 2000).

Although Mexico produced about 5% of global crude oil, it did not have the refinery capacity to meet domestic demand for gasoline. The completion of the refinery upgrade at Pemex's Cadereyta refinery brought capacity close to demand. Five additional upgrade projects were planned to transform the country's trade balance for gasoline. Mexican refineries were unable to process heavy maya crude into sufficient quantities of motor fuels. Pemex invested in U.S. refineries in Texas to ensure steady markets for their crude oil but had been unable to find the capital to modernize its own refineries. Revamping at Cadereyta expanded capacity for diesel, jet fuel, and gasoline. Sulfur production was expected to be about 480 t/d with further expansion of 80 t/d, eventually reaching about 450,000 t/yr. Sulfur production was expected to be similar when the Madero upgrade was completed. Other planned modernization projects include those of Minatitlan, Salamanca, Tula, and Salina Cruz. No details on progress or expected sulfur recovery capacities were available. Additional sulfur supplies were expected from new natural gas processing operations, perhaps more than 500,000 t/yr from a single project (Cunningham, 2000c).

Pemex had long-term supply contracts with U.S. refiners Premcor Inc., ExxonMobil, and Marathon Ashland Petroleum LLC (Cunningham, 1999b). Pemex was involved in a joint venture with Shell at Deer Park, TX (North America Sulphur Service, 1999a).

Netherlands Antilles.—PdVSA's Netherlands Antilles affiliate, Refinería Isla, was upgrading its refinery in Curaçao, including its sulfur recovery unit. Completion was expected in 2002 (Sulphur, 2000v).

Philippines.—Crew Development Corp. of Canada was planning a nickel pressure acid leach project on Mindoro Island in the Philippines. In order to mitigate the costs of sulfur, a high-cost factor in development of the nickel operation, Crew investigated the possibility of mining sulfur from the Pamplona sulfur deposit on Negros Island, also in the Philippines. Reserves at Pamplona were set at 60 Mt with 30.8% sulfur, 13.8% of which was elemental sulfur and 17% was in sulfides (Industrial Minerals, 2000). With sulfur prices at low levels worldwide and no change expected, it seemed unlikely that the Philippine sulfur deposit would be developed. The cost of development and production would need to be very low to allow profitable processing.

Poland.—As in many countries with improving economies, oil refineries in Poland were upgrading their sulfur recovery units to meet air quality regulations forbidding the release of sulfur dioxide into the atmosphere (Sulphur, 1999b). Recovered sulfur, however, remains a secondary source of sulfur in Poland.

Rich sulfur deposits were discovered in Poland in 1954, and production began at the first surface mine late in that decade. Since that time, five native sulfur mines have been developed in Poland. The first two, Piaseczno and Machów, were surface mines that utilized conventional mining methods. The other three mines, Grzybów, Jeziórko, and Osiek, used the Frasch method with modifications to work with the geologic conditions in Poland. At the peak of Polish sulfur production in 1980, more than 5 Mt of sulfur could be produced from three mines, Grzybów, Jeziórko, and Machów. Three of the mines closed and were being recultivated as lakes and other recreation areas, leaving Jeziórko and Osiek operating in 1999 (Karolak, 1997).

Polish sulfur entered the global market in 1961, when the sulfur shipping facilities in Gdańsk were completed. In 1980, about 3.8 Mt (nearly 75%) of Polish production was exported, mostly to other European countries. Since the early 1990s, low global prices have made it extremely difficult for the discretionary sulfur producers to compete in the global market, and those markets have dwindled for the Polish industry (Karolak, 1997). Polish Frasch production increased by 17% in 2000, the first increase since 1995. Domestic consumption and exports were higher than the previous year. Poland's largest sulfur customer was Morocco; Poland had a sulfur-phosphate rock swap agreement with a Moroccan phosphate producer

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(Fertilizer Focus, 2001).

Qatar.—Qatar Liquified Gas Co. was revamping and expanding two sulfur recovery units at Ras Laffan, with completion expected in 2002 (Sulphur, 2000y).

Russia.—The Astrakhan Gas Processing Plant (AGP) was the largest single source of recovered sulfur in the world. During 2000, the operation was producing 3.6 Mt/yr and expansion projects nearing completion promised to bring the total to 4.2 Mt/yr by 2002. Final expansions were expected to be completed in 2003, bringing sulfur production to 4.5 Mt/yr. Formed sulfur from this site was exported through the port of Novorossiysk, at which a liquid sulfur terminal was under consideration. Exports of AGP products from this port were limited to about 1 Mt/yr because the rail line from the plant to the port was unable to handle more than that (Sulphur, 2000m).

Russia's largest natural gas producer, Gazprom, approved a study on the feasibility of building a liquid sulfur terminal at the Black Sea port of Novorossiysk to handle 1 Mt/yr of molten sulfur from Gazprom's Astrakhan natural gas field. North Africa and other locations in the Mediterranean would be logical markets for the material. In 2000, Astrakhangazprom produced about 3.6 Mt with sales of 3.9 Mt of solid sulfur, including sales from stocks (Sulphur, 2000d).

Russian exports were more than 3 Mt in 2000. The 25% increase from the previous year was a result of increased production from Astrakhan and an effort to reduce stocks. Israel was Russia's largest customer. Russian sulfur has displaced material from Canada and the Middle East in important markets in north Africa, southern Europe, and the Mediterranean area (Fertilizer Week, 2001).

Russian industry was beginning to deal with pollution issues, sometimes with foreign assistance. Perneftegas, a major Russian natural gas and oil producer, revamped one of its units to reduce sulfur dioxide emissions (Sulphur, 2000m). The copper smelter at Karabash, one of Russia's five most polluted cities, was renovating the gas cleaning systems to recover sulfuric acid. The Government of Norway was paying for environmental improvements at the Pechanganickel operation owned by Norilsk Nickel Corp. on the Kola Peninsula. Sulfuric acid recovery was to be expanded to reduce the amount of sulfur dioxide released in Russia that contaminates other countries that border Russia (Sulphur, 2001g).

Saudi Arabia.—The Hawiyah gas plant in Saudi Arabia was 4 months ahead of schedule and was expected to begin production in December 2001. Ramp-up was expected to begin in June. This was the first supply plant of Saudi Arabia's master gas system to process gas not associated with crude oil production (Sulphur, 2000u).

Spain.—A new 900,000 t/yr sulfuric acid plant was commissioned by Fertiberia S.A. at Huelva in southern Spain. The new sulfuric acid plant was expected to use about 200,000 t/yr of elemental sulfur from Spanish suppliers and imported sulfur from Canada, France, and Russia (Fertilizer Markets, 2000a). The new sulfuric acid plant replaced three pyrite-based acid plants (Fertilizer Focus, 2001)

Spain's Asturiana de Zinc, S.A., was building a new zinc processing plant in San Juan de Nieva. Included in the project was a sulfuric acid plant (Sulphur, 2000j).

Ukraine.—Ukraine, once a major producer of native sulfur using Frasch and conventional mining methods, has not mined any sulfur for several years. The country planned to flood one of its idle surface mines to be used as a reservoir (Sulphur, 2000m).

Venezuela.—Venezuela's Orinoco Basin was one of the world's largest resources of crude oil. If recent developments in refining technology had not provided the means for upgrading the crude, it could not have been developed (Sulphur, 2000s). Upgraded crude production from the Orinoco Basin could result eventually in the production of 8 Mt/yr of sulfur, with about 5 Mt/yr of that being produced in Venezuela, and the rest, at refineries in other countries, very possibly in the United States (Cunningham, 2000e).

Heavy oil upgrading facilities at the port of Jose progressed. The first of the projects to upgrade high-sulfur Orinico crude oil was expected to be completed early in 2001. Petrozuata, a joint venture between Conoco Inc. and PdVSA that was designed to produce synthetic crude oil for domestic refining and export, would also produce byproduct petroleum coke and elemental sulfur. The Cerro Negro project, owned by ExxonMobil, PdVSA, and Germany's Veba Oel AG, will produce synthetic crude oil for refining at ExxonMobil's and PdVSA's refinery in Chalmette, LA, and in Germany. Production was expected to begin in 2001. The largest upgrader project at Jose is scheduled for completion in 2002. That operation is owned 47% by TotalFinaElf, 38% by PdVSA, and 15% by Statoil ASA of Norway (Sulphur, 2001e).

Sulfur production from the first heavy oil upgrader project at the Jose complex will undergo a forming process before being shipped overseas. Once the heavy oil upgrading projects are completed at Jose, the terminal will provide an additional 400,000 t/yr of sulfur to the world market (Sulphur, 2000h).

PdVSA also is involved in a joint venture for processing Venezuelan crude at the Phillips refinery in Sweeny, TX. PdVSA and Phillips spent $540 million to build a coker and a vacuum distillation unit to be operated by Merey Sweeny Limited Partnership (Sulphur, 2001e).

In addition to upgrader projects that will add sulfur recovery capacity in Venezuela, PdVSA was updating existing petroleum crackers to meet new standards for reducing sulfur emissions. The upgrade was designed to raise the recovery at two refineries to 99.2% from a maximum of 94%. Venezuela established new standards of 98.9% recovery (Chemical Market Reporter, 2000b).

Zambia.—Roan Antelope Mining Corp. of Zambia planned to develop of a new SX-EW project at its Muliashi North Mine. The project required construction of an elemental-sulfur-based sulfuric acid plant (Sulphur, 2000t).

Current Research and Technology

Biodesulfurization.—Enchira Biotechnology Corp. received $900,000 from the U.S. Department of Energy for research to develop a bacterial process for removing sulfur from gasoline. Enchira, formerly Energy Biosystems Corp., was operating a pilot plant in Alaska to remove sulfur from diesel using a similar process. Thus far, the diesel process had struggled to meet cost targets and did not remove sulfur as thoroughly as projected. Enchira has stated that because gasoline is a more powerful solvent than diesel, it may be difficult to adapt the process to gasoline. Genetic modifications to the bacteria enabled faster adaptation to differing environments (Sulphur, 2000b).

Development of a biological process that worked quickly enough to use in an industrial facility had been the major hurdle

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to implementation. Biocatalytic desulfurization, when fully developed, was expected to be significantly less costly than more common technology and was identified as a possible way for small refiners to meet more stringent sulfur requirements (U.S. Department of Energy, 2000).

Injection of Sulfur Dioxide.—Alberta Sulphur Research Ltd. was looking into the possibility of developing a process for injecting sulfur dioxide into a sour gas reservoir. The sulfur dioxide would react with the hydrogen sulfide in the deposit to form elemental sulfur and water, the same reaction used in sulfur recovery units. Not only would the process eliminate a sulfur disposal problem for the operation, but it also would produce high quality steam that could be used elsewhere in the operation. This process also could help to eliminate excess stocks of sulfur and at the same time produce electricity for sale to the power grid. Investigation of this new idea for sulfur disposal has just begun; but if it is successfully developed, it could relieve the worldwide oversupply situation (Connock, 2001).

New Processes for Removing Sulfur from Fuels.—BP developed a gasoline desulfurization process called olefinic alkylation of thiophenic sulphur (OATS). OATS was capable of removing 99.5% of the sulfur compounds in a major gasoline blending component, naptha produced at fluid catalytic cracking units, without significantly reducing the quality of the fuel or reducing the quantity of fuel produced. The OATS process was simple and easily retrofitted to an existing operation. The process involved pretreatment of the feed by washing with acid, neutralization of the spent liquor, the OATS reaction section, the production fractionation section, and a naptha hydrotreater. Two small demonstration units began operation at BP's Texas City, TX, refinery, and a larger scale trial was completed at the company's joint-venture refinery in Bayern, Germany (Sulphur, 2001d). ExxonMobil has developed a new catalyst for conventional hydrotreating processes, but it minimizes quality degradation of the product (Exxon Mobil Corp., 2000).

Phillips Petroleum developed a process that stripped sulfur from gasoline blending stocks by using a regenerative adsorbent. The benefits of this process as compared with some desulfurizing processes were that the reduction in octane level was limited, the volume loss was low, and the vapor pressure was maintained. The process's first commercial application at Phillips Petroleum's Borger, TX, facility was set to go onstream in early 2001. Phillips Petroleum licensed the technology to Marathon Ashland Petroleum for use at all of its seven refineries (Sulphur, 2000q).

Phillips Petroleum adapted its S Zorb technology to handle diesel fuels. Pilot plant testing of the processes was ongoing at the company's research and development center. The S Zorb technology did not consume significant quantities of hydrogen, a high-cost component of many desulfurization processes (Sulphur, 2000p).

Reinjection of Hydrogen Sulfide.—Reinjection of the sulfur as hydrogen sulfide into an appropriate underground reservoir was an attractive alternative in some instances at some natural gas operations but was seldom feasible at oil refineries. In acid gas reinjection from sour gas processing, the hydrogen sulfide and carbon dioxide were separated from the gas using standard separation techniques and recompressed into a suitable injection zone. The suitability of the injection zone was influenced by its distance from the processing facility and could be a large aquifer, a depleted reservoir, or a zone producing sour fluids. A depleted reservoir was especially attractive because its size and original pressure were already known, making the determination of its holding capacity easier to determine. The sour gases also could be reinjected into a producing deposit.

Reinjection was being used at many small-scale operations, especially in Canada, but it had not been demonstrated that reinjection would work on a large scale. It was essential that the reinjected gases not escape from the reservoir by migration into adjacent reservoirs or aquifers or into the atmosphere by migration through an outcrop.

With large-scale reinjection schemes, the energy balance would be a large factor in determining its feasibility. Without the sulfur recovery plant that produces energy that can be used elsewhere in the operation, steam production using an external energy source, such as natural gas or electricity, was required. Using natural gas presented the situation of producing carbon dioxide emissions in order to reinject carbon dioxide. A determination on whether the environmental benefit of reinjecting carbon dioxide was canceled out by the carbon dioxide emissions produced for that reinjection was needed.

A feasibility study conducted by Abu Dhabi National Oil Co. showed that a large scale reinjection project should have favorable energy balance greenhouse gas considerations. The technical and operating challenges were yet to be resolved (Connock, 2001).

Sulfuric Acid from Powerplants.—Powerspan Corp. developed a process for converting sulfur dioxide emissions from coal-fired power generation to commercial grade sulfuric acid. A full-scale demonstration project was being installed at FirstEnergy Corp.'s Eastlake, OH, generating plant. The electrocatalytic oxidation process (ECO) was designed to cut nitrogen oxide and sulfur dioxide emissions simultaneously at lower installation and operation costs than similar emission reduction processes. The Eastlake project was expected to cut nitrogen oxide, sulfur dioxide, mercury, and fine particulate matter emissions by more than 70%, 50%, 70%, and 90%, respectively, beginning early in 2001 (Sulphur, 2000r).

Sulfur Paving Materials.—Liquified Gas, a subsidiary of Astrakhangazprom, built a pilot plant to produce materials for trials of sulfur-extended construction materials. The plant will have the capacity to produce 50,000 t/yr of sulfur polymer cement and 32,000 t/yr of sulfur-extended asphalt cement. Other countries of the former Soviet Union that announced plans to pursue the use of sulfur in paving are Turkmenistan and Kazakhstan (Sulphur, 2001a).

Outlook

The sulfur industry continued on its path of increased production, slower growth in consumption, higher stocks, and expanded world trade. U.S. production from petroleum refineries is expected to increase substantially in the next few years as expansions, upgrades, and new facilities at existing refineries are completed, enabling refiners to increase thoughput of crude oil and to process higher sulfur crudes. Production from natural gas operations varies but is usually between 2.0 and 2.2 Mt/yr. Output is expected to remain at about that level. Worldwide recovered sulfur should continue to increase. Refineries in developing countries should begin to improve environmental protection measures and eventually approach the environmental standards of plants in Japan, North America, and Western Europe.

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Experts from the natural gas industry estimate that the world demand for natural gas will grow by 2.5% per year during the next 20 years, a total 50% increase in demand. Producing 50% more gas means recovering at least an additional 50% in sulfur from that source. Future gas production, however, is likely to come from deeper, hotter, and sourer deposits that will result in even more excess sulfur production unless more efforts are made to develop new, large-scale uses for sulfur. Other alternative technologies for reinjection and long-term storage to eliminate some of the excess sulfur supply will require further investigation in order to handle the quantity of surplus material anticipated (Hyne, 2000).

Byproduct sulfuric acid production will remain depressed in the United States as long as the copper smelters remain idle. With the copper industry's switch to lower cost production processes and producing regions, it could be many years before U.S. byproduct acid production again approaches the level it reached in 1998. Worldwide, the outlook is different. Copper production costs in many countries are lower than in the United States, so that acid production from those countries has not decreased as drastically, and increased production is more likely. Environmental controls have been less of a concern in developing countries in the past. Many copper producers, however, in these and even in developed countries are installing more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Planned and in-progress improvement projects could increase byproduct acid production to 52 Mt by 2010 or the equivalent of about 17 Mt of sulfur from 10 Mt (3.3 Mt of sulfur) in 1999 (Sulphur, 1999a).

Frasch and pyrites production, however, have little chance of significant long-term increases. Because of the continued growth of elemental sulfur recovery for environmental reasons rather than demand, discretionary sulfur has become increasingly less important. Frasch sulfur has become the high-cost process for sulfur production. Pyrites, with significant direct production costs, are an even higher-cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output should show a steady decline. The decreases will be pronounced when large operations are closed outright for economic reasons such as was the case in 2000.

Sulfur and sulfuric acid will continue to be important in agricultural and industrial applications, although consumption will not equal production. World sulfur demand for fertilizer is forecast to increase at about 2.7% per year for the next 10 years; industrial demand is predicted to grow at 2.3% per year.

The most important changes in sulfur consumption will be in location. Phosphate fertilizer production, where most sulfur is consumed, is projected to increase by about 2.3% per year through 2010. With new and expanding phosphate fertilizer capacity in Australia, China, and India, sulfur demand will grow in these areas at the expense of some phosphate operations elsewhere, thus transferring sulfur demand rather than creating new. The effects were already being felt by the U.S. phosphate industry, reflected in the permanent closure of some facilities and reduced production at others. U.S. phosphate products supply domestic requirements, but a large portion of U.S. production is exported. China and India are primary markets for United States fertilizers. As the phosphate fertilizer industries develop in these countries, some of the markets for U.S. material could be lost. Sulfur will be required for phosphate production at new operations, and more producers will be competing for those markets.

Use of sulfur directly or in compounds as fertilizer should increase, but this use will be dependent on agricultural economies and increased acceptance of the need for sulfur in plant nutrition. If widespread use of plant nutrient sulfur is adopted, sulfur consumption in that application could be significant; thus far, growth has been slow.

Industrial sulfur consumption has more prospects for growth than in recent years but still less than agriculture and not enough to consume any surplus production. Conversion to or increases in copper leaching by producers, who require significantly more sulfuric acid for the leaching operations than was used in 2000, bode well for the sulfur industry. Nickel PAL operations were demanding increased quantities of sulfur. Changes in the preferred methods for producing oxygenated gasoline, especially in Canada and the United States, might result in additional alkylation capacity that would require additional sulfuric acid. Other industrial uses show less potential for expansion. Estimates show sulfur production exceeding consumption by 3 Mt/yr for the next 20 years, and worldwide inventories reaching 80 Mt by 2020 (Hyne, 1999). The potential exists for involuntary sulfur production of 80 to 100 Mt/yr by 2050, representing a 120% increase in the time period that could be required to develop viable energy alternatives to fossil fuels (Cunningham, 2000e)

Unless significant new uses for elemental sulfur are implemented, the oversupply situation will result in tremendous stockpiles accumulating around the world. In the 1970s and 1980s, research was conducted that showed the effectiveness of sulfur in several construction uses that held the promise of consuming huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were found to be superior to the more traditional products, but their use has been very limited. Interest in these materials seemed to be increasing but only in additional research. No large-scale projects were announced that would require sizable quantities of sulfur. It may be necessary to revisit these proposals to avoid building mountains of sulfur in the not-too-distant future.

References Cited

Albian Sands Energy Inc, 2000, Construction progress—Athabasca oil sands project: Muskeg River Mine Update Newsletter, v. 6, Fall, p. 1.

BP Amoco p.l.c., 1999, BP Amoco merger completed: London, BP Amoco p.l.c. press release, January 1, 1 p.

Chang, Joseph, 1999, BP Amoco to buy Atlantic Richfield in $26 Bn stock deal: Chemical Market Reporter, v. 255, no. 15, April 12, p. 1, 18.

Chang, Thi, 2000, Worldwide refining capacity steady in the past year: Oil & Gas Journal, v. 98.51, December 18, p. 56-64.

Chemical & Engineering News, 2000, On-purpose sulfur to cease in the U.S.: Chemical & Engineering News, v. 78, no. 31, July 31, p. 15.

Chemical Market Reporter, 2000a, EC sanctions TotaFina's takeover of Elf: Chemical Market Reporter, v. 257, no. 7, February 14, p. 8.

———2000b, Venezuela begins sulfur recovery upgrades: Chemical Market Reporter, v. 257, no. 8, February 21, p. 15.

———2001, Refiners attack new sulfur level rules: Chemical Market Reporter, v. 259, no. 1, p. 5.

Chevron Corp., 2000a, Chevron finalizes additional stake in Tengiz joint venture: San Francisco, Chevron Corp. press release, August 29, 1 p.

———2000b, Supplement to the 1999 annual report: San Francisco, Chevron Corp., February 23, 52 p.

Connell, Dave, Ormiston, Bob, Amott, Nick, and Cullum, Irene, 2000, Gas-plant update moves Tengiz field toward 2004 producing target: Oil & Gas Journal, v. 98.24, June 12, p. 64-72.

Connock, Lisa, 2001, Acid gas re-injection reduces sulphur burden: Sulphur, no. 272, January-February, p. 35-41.

Cunningham, Chris, 1999a, Chinese demand more refined: Sulphur, no. 262,

Digitized by Google

May-June, p. 16-22.
———1999b, Sour imports fill the Gulf: Sulphur, no. 263, July-August, p. 31-37.
———2000a, Demand from nickel refiners shapes up: Sulphur, no. 279, September-October, p. 31-34.
———2000b, Disunity in a united city: Sulphur, no. 269, July-August, p. 13-17.
———2000c, Heavy going for Mexico's refineries: Sulphur, no. 271, November-December, p. 29-31.
———2000d, Oil price underpins Gulf brimstone output: Sulphur, no. 267, March-April, p. 13-18.
———2000e, Sulphur matters on the bay: Sulphur, no. 271, November-December, p. 17-21.
———2001, Oil sands bonanza: Sulphur, no. 272, January-February, p. 27-33.
Duke Energy Corp., 2001, Duke Energy Corp. 2000 annual report: Charlotte, NC, Duke Energy Corp., 24 p.
El Paso Corp., 2001, El Paso announces new corporate identity: Houston, El Paso Corp. press release, February 5, 1 p.
El Paso Energy Corp., 2001, El Paso Energy completes merger with Coastal, creating the world's leading natural gas company: Houston, El Paso Energy Corp. press release, January 29, 3 p.
Exxon Mobil Corp., 2000, ExxonMobil announces industry leading sulfur technology: Houston, Exxon Mobil Corp. press release, August 11, 2 p.
Fertilizer Focus, 2001, Sulphur trade developments: Fertilizer Focus, v. 18, no. 3, April, p. 28-37.
Fertilizer Markets, 1999, Decline in Chinese pyrites aids Canadian S exports: Fertilizer Markets, v. 10, no. 9, September 13, p. 2-3.
———2000a, Fertibieria brings huge acid plant up: Fertilizer Markets, v. 11, no. 10, October 2, p. 2-3.
———2000b, Jordan: Fertilizer Markets, v. 11, no. 11, October 16, p. 10.
———2000c, Main Pass closed: Fertilizer Markets, v. 11, no. 4, September 4, p. 9.
———2001, Freeport sells Culberson asset, sees 80$ million Main Pass deal: Fertilizer Markets, v. 11, no. 23, January 5, p. 2.
Fertilizer Week, 2000, Norddeutsche restart—H_2SO_4 shipments resume: Fertilizer Week, v. 14, no. 29, p. 2.
———2001, Russian sulphur exports surge; Israel in spotlight: Fertilizer Markets, v. 14, no. 43, March 12, p. 4.
Garritsen, L.A., Desai, P.H., and Inoue, Yoshimasa, 2000, Catalysts play a large part in ultra-low sulfur fuel: Oil & Gas Journal, v. 98.41, October 9, p. 76-80.
Goodwin, Daniel, 2000, $1-billion uprade prepares Canadian refinery for future specs: Oil & Gas Journal, v. 98, no. 13, March 27, p. 45-51.
Green Markets, 1999, Market watch—West Coast: Green Markets, v. 23, no. 1, January 4, p. 9.
———2000, Sulfur: Green Markets, v. 24, no. 37, September 11, 2000, p. 8.
———2001, Florida sulfur melting plant approved: Green Markets, v. 25, no. 4, January 22, p. 9-10.
Haynes, Williams, 1959, Brimstone—The stone that burns: Princeton, NJ, D. Van Nostrand Co., Inc., 293 p.
Hess, Glenn, 2000, EPA's diesel reduction plan draws opposition form industry: Chemical Market Reporter, v. 257, no. 26, June 26, p. 28.
Hoffman, 2000, Chevron and Texaco plan to unite: Chemical Market Reporter, v. 258, no. 17, October 23, p. 5.
Hyne, J.B., 1999, S_8 after Y2K?: Sulphur, no. 260, January-February, p. 20-25.
———2000, An invisible hill to climb: Sulphur, no. 269, July-August, p. 3.
Industrial Minerals, 2000, Crew to acquire Pamplona sulphur: Industrial Minerals, no. 392, May, p. 12.
Karolak, Jozef, 1997, The Polish sulphur industry, *in* International Fertilizer Industry Association Production and International Trade Committee Meeting, Warsaw, Poland, 1997, Proceedings: Warsaw, International Fertilizer Industry Association, v. III, p. 85-92.
Kitto, Mike, 2000, The sulphur market—Developments and trends: Sulphur, no. 269, July-August, p. 19-25.
Larson, L.P., and Marks, A.L., 1955, Sulfur and pyrites: Bureau of Mines Minerals Yearbook 1954, v. I, p. 1119-1143.
Manriquez, Leonardo, Moreno, Abel, and Tenorio, E.R., 2000, Guide to world crudes—Four Mexican crude assays updated: Oil & Gas Journal, v. 98.20, May 15, p. 54-57.
McCoy, Michael, 1999, Sulfuric acid market rocked by copper: Chemical & Engineering News, v. 77, no. 40, October 4, p. 13-16.
McMoRan Exploration Co., 2000a, McMoRan Exploration Co. 1999 annual report and form 10-K: New Orleans, McMoRan Exploration Co., 55 p.
———2000b, McMoRan Exploration Co. announces plan to operate solely in oil & gas exploration and production by suspending Main Pass sulphur production and selling remaining sulphur assets—Reports second quarter and six months 2000 results: New Orleans, McMoRan Exploration Co. press release, July 20, 9 p.
Moyse, B.M., 2000, Process, catalyst choices key to producing 30-ppm sulfur fuels: Oil & Gas Journal, v. 98.41, October 9, p. 72-74.
North America Sulphur Service, 1999a, News and developments: Sulphur Newsletter, v. 10, no. 5, May, p. 3.
———1999b, News and developments: Sulphur Newsletter, v. 10, no. 12, December, p. 3.
———2000a, Focus on recent developments in US recovered sulfur and the supply outlook: Sulphur Newsletter, v. 11, no. 4, April, p. 1.
———2000b, News and developments: Sulphur Newsletter, v. 11, no. 2, February, p. 2-3.
———2000c, News and developments: Sulphur Newsletter, v. 11, no. 3, March, p. 2.
———2000d, News and developments: Sulphur Newsletter, v. 11, no. 7, July, p. 4.
———2000e, News and developments: Sulphur Newsletter, v. 11, no. 8, August, p. 2.
Ober, J.A., 1994, Sulfur: U.S. Bureau of Mines Minerals Yearbook 1993, v. I, p. 1165-1193.
Oil & Gas Journal, 1999, A description of Canadian oilsands characteristics: Oil & Gas Journal, v. 97, no. 26, June 28, p. 48.
———2000a, BP Amoco signs deal with FTC, acquires ARCO: Oil & Gas Journal, v. 98, no. 17, April 24, p. 26-27.
———2000b, EPA issues rule limiting US gasoline sulfur: Oil & Gas Journal, v. 98, no. 1, January 3, p. 26-27.
———2000c, Refinery completes revamp to accomodate Venezuelan crude: Oil & Gas Journal, v. 98.43, October 23, p. 50.
———2000d, Shell Canada proceeds with oilsands project: Oil & Gas Journal, v. 98, no. 2, January 10, p. 22-23.
———2001, Government developments: Oil & Gas Journal, v. 99.1, January 1, p. 7.
Outokumpu Oyj, 2000, Outokumpu and Codelco to jointly develop a new copper flash smelting application: Espoo, Finland, Outokumpu Oyj press release, October 12, 2 p.
Packer, Phil, 2000, European refiners should not expect return on fuel-quality investments: Oil & Gas Journal, v. 98.48, November 27, p. 68-69.
PentaSul North America Sulphur Review, 2000a, News and developments: PentaSul North America Sulphur Review, v. 11, no. 12, December, p. 2.
———2000b, The US Gulf market is the focus of new sulphur logistical developments: PentaSul North America Sulphur Review, v. 11, no. 11, November, p. 2.
———2001, Canada: PentaSul North America Sulphur Review, v. 12, no. 1, January, p. 3.
Phelps Dodge Corp., 1999, Phelps Dodge Morenci to convert all copper production into leaching—Will see unit cost reduction of 10 percent: Phoenix, AZ, Phelps Dodge Corp. news release, September 1, 2 p.
QNI Pty. Ltd., 2000, QNI elects to proceed with development of the Ravensthorpe nickel project: Brisbane, Australia, QNI Pty. Ltd. press release, June 4, 2 p.
Richardson, Neil, and du Preez, Pieter, 2000, Study says 2005 EU product specs may cost refiners up to $9 billion: Oil & Gas Journal, v. 98.48, November 27, p. 64-67.
Sears, Gerry, 2000, According to plan: Sulphur, no. 268, May-June, p. 19-26.
Shelton, J.E., 1978, Sulfur and pyrites: U.S. Bureau of Mines Minerals Yearbook 1976, v. I, p. 1287-1307.
Stell, Jeannie, 2000, 2000 worldwide refining survey: Oil & Gas Journal, v. 98.57, December 18, p. 66-120.
Stevens, Jason, 1998, Oil sands projects gather pace: Sulphur, no. 254, January-February, p. 27-30.
Sulfuric Acid Today, 1999, Phelps Dodge, copper producers convert to low-cost production methods: Sulfuric Acid Today, v. 5, no. 2, Fall/Winter, p. 12.
Sulphur, 1999a, A bright spot on the horizon: Sulphur, no. 260, January-February, p. 3.
———1999b, Analyzers aid air quality program: Sulphur, no. 261, March-April, p. 10.
———1999c, An underground revolution: Sulphur, no. 261, March-April, p. 3.
———1999d, Germany aims for early fuel sulphur reductions: Sulphur, no. 264, September-October, p. 11.
———2000a, Acid leach supply contract for Kennecott: Sulphur, no. 270, September-October, p. 14.
———2000b, DOE funds bugs for cleaner gas: Sulphur, no. 269, July-August, p. 10.
———2000c, Finn-Chilean technology mix to upgrade smelter output: Sulphur, no. 271, November-December, p. 10.
———2000d, Gazprom approves liquid S terminal study: Sulphur, no. 269, July-August, p. 10-11.
———2000e, Government, military aim high in S control: Sulphur, no. 271, November-December, p. 13.
———2000f, Iranian brimstone goes premium: Sulphur, no. 267, March-April, p. 8.
———2000g, JMPC cuts costs with Iraqi imports: Sulphur, no. 271, November-December, p. 10-11.

Digitized by Google

———2000h, Koch in sulphur handling deal with Petrozuata: Sulphur, no. 270, September-October, p. 14.
———2000i, Latest developments in leaching technology for metal ores: Sulphur, no. 269, July-August, p. 31-40.
———2000j, Lurgi to boost Asturiana acid output: Sulphur, no. 267, March-April, p. 10.
———2000k, News in brief: Sulphur, no. 267, March-April, p. 10.
———2000l, News in brief: Sulphur, no. 269, July-August, p. 10.
———2000m, News in brief: Sulphur, no. 270, September-October, p. 12.
———2000n, Noranda revives Chilean smelter plans: Sulphur, no. 266, March-no. 267, April, p. 8.
———2000o, Petro-Canada considers bitumen upgrader: Sulphur, no. 271, November-December, p. 10.
———2000p, Phillips develops S Zorb for refinery diesel streams: Sulphur, no. 271, November-December, p. 12.
———2000q, Phillips sells field license on de-S process: Sulphur, no. 269, July-August, p. 9-10.
———2000r, Power station to produce saleable acid: Sulphur, no. 269, July-August, p. 10.
———2000s, Quote of the year?: Sulphur, no. 270, September-October, p. 3.
———2000t, RAMCOZ gives go-ahead to S burner: Sulphur, no. 269, July-August, p. 11.
———2000u, Sulphur-rich gas plant to beat project schedule: Sulphur, no. 271, November-December, p. 12.
———2000v, Technip wins Ras Laffan upgrade award for sulfur recovery: Sulphur, no. 269, July-August, p. 8.
———2001a, AGP to supply sulphur cement, asphalt trials: Sulphur, no. 272, January-February, p. 12-14.
———2001b, All at sea: Sulphur, no. 272, January-February, p. 3.
———2001c, Bapco awards front end contract for diesel upgrade: Sulphur, no. 272, January-February, p. 11.
———2001d, BP tests new low sulphur gasoline technology: Sulphur, no. 272, January-February, p. 42-43.
———2001e, Jose upgrader due on stream: Sulphur, no. 272, January-February, p. 18.
———2001f, Koch subsidiary digs further into oil sands property: Sulphur, no. 272, January-February, p. 18.
———2001g, News in brief: Sulphur, no. 272, January-February, p. 11.
———2001h, Norddeutsche considers more copper/acid output: Sulphur, no. 272, January-February, p. 12.
———2001i, Pyrites burner switches to local brimstone: Sulphur, no. 272, January-February, p. 12.
Syncrude Canada Ltd., 2000, Syncrude's Aurora Mine heralds new era of energy production for Canada: Fort McMurray, Canada, Syncrude Canada Ltd. news release, August 17, 2 p.
U.S. Census Bureau, 2001, Inorganic fertilizer materials and related products [MQ325B(00)-5]: U.S. Census Bureau, July, 6 p.
U.S. Department of Energy, 2000, Energy Department looks to small Alaska refiner to apply biological process to meet new diesel sulfur standards: Washington, U.S. Department of Energy press release, August 16, 2 p.
Westervelt, Robert, 2000, Chevron agrees to acquire Texaco for $45 billion: Chemical Week, v. 162, no. 40, October 25, p. 12.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Sulfur. Ch. in Mineral Commodity Summaries, annual.
Sulfur. Ch. in Minerals Yearbook, annual.
Sulfur. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Sulfur. Mineral Industry Surveys, monthly.

Other

Chemical & Engineering News, weekly.
Chemical Engineering, weekly.
Chemical Market Reporter, weekly.
Chemical Week, weekly.
European Chemical News (London), weekly.
Fertilizer Focus (London), monthly.
Fertilizer International (London), monthly.
Fertilizer Markets, weekly.
Green Markets, weekly.
Industrial Minerals (London), monthly.
Oil & Gas Journal, weekly.
PentaSul North America Sulphur Review, monthly.
Phosphorus & Potassium (London), bimonthly.
Sulfur. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Sulphur (London), bimonthly.

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TABLE 1
SALIENT SULFUR STATISTICS 1/

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production:					
Frasch e/	2,900	2,820	1,800	1,780	900
Recovered 2/	7,480	7,650	8,220	8,220	8,380
Other	1,430	1,550	1,610	1,320	1,030
Total e/	11,800	12,000	11,600	11,300	10,300
Shipments:					
Frasch	W	W	W	W	W
Recovered 2/ 3/	10,400	10,400	10,500	9,800	9,500
Other	1,430	1,550	1,610	1,320	1,030
Total	11,800	11,900	12,100	11,100	10,500
Exports:					
Elemental 4/	855	703	889	685	762
Sulfuric acid	38	39	51	51	62
Imports:					
Elemental	1,960	2,060	2,270	2,580	2,330
Sulfuric acid	678	659	668	447	463
Consumption, all forms	13,600	13,900	14,100	13,400	12,500
Stocks, December 31, producer, Frasch and recovered	646	761	283	451	208
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	W	W	W	W	W
Recovered 2/ 3/	$355,000	$375,000	$306,000	$371,000	$239,000
Other	$85,800	$98,100	$77,100	$66,400	$55,100
Total	$441,000	$473,000	$383,000	$437,000	$295,000
Exports, elemental 5/	$51,700	$36,000	$35,400	$35,800	$53,700
Imports, elemental	$70,200	$64,900	$58,400	$51,600	$39,400
Price, elemental, f.o.b. mine or plant, dollars per metric ton	$34.11	$36.06	$29.14	$37.81	$24.73
World, production of all forms, including pyrites	55,200 r/	57,100	57,100 r/	57,700 r/	57,200 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Recovered."
1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.
2/ Includes U.S. Virgin Islands.
3/ Includes corresponding Frasch sulfur data.
4/ Includes exports from the U.S. Virgin islands to foreign countries.
5/ Includes value of exports from the U.S. Virgin Islands to foreign countries.

TABLE 2
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	1999			2000		
		Shipments			Shipments	
State	Production	Quantity	Value	Production	Quantity	Value
Alabama	336	336	12,700	320	321	7,970
California	1,070	1,070	5,270	1,150	1,140	5,660
Illinois	418	417	11,300	444	444	5,900
Louisiana	1,110	2,590 2/	W	1,070	2,180 2/	W
Michigan and Minnesota	33 r/	33 r/	818	34	34	483
Mississippi	527	528 r/	10,200	525	533	20,100
New Mexico	47	47	253	48	48	(3/)
North Dakota	51	51	487	50	50	(3/)
Ohio	80	80	2,300	112	111	2,210
Texas	2,610	2,770 2/	153,000 2/	2,760	2,770	80,300
Washington	95	96	224	113	110	27
Wyoming	1,080	1,050	21,700	1,030	1,030	16,900
Other 4/	763 r/	736 r/	152,000	717	730	99,800
Total	8,220	9,800	371,000	8,380	9,500	239,000

See footnotes at end of table.

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TABLE 2--Continued
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE 1/

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes corresponding Frasch sulfur data.
3/ Some sulfur producers in this State incur expenses to make their production available to consumers.
4/ Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Louisiana (value), Montana, New Jersey, Pennsylvania, Utah, Virginia, Wisconsin, and the U.S. Virgin Islands.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES,
BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT 1/

(Thousand metric tons)

	1999		2000	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	228	220	240	246
Natural gas	45	45	43	42
Total	272	265	283	288
PAD 2:				
Petroleum and coke	821	820	882	882
Natural gas	53	53	53	53
Total	874	873	935	935
PAD 3: 2/				
Petroleum	3,880	W	3,890	W
Natural gas	847	W	904	W
Total	4,730	6,350 3/	4,800	5,940 3/
PADs 4 and 5:				
Petroleum	1,280	1,270	1,340	1,320
Natural gas	1,070	1,040	1,020	1,020
Total	2,350	2,310	2,360	2,340
Total petroleum and coke	6,210	W	6,360	W
Total natural gas	2,010	W	2,020	W
Grand total	8,220	9,800 3/	8,380	9,500 3/

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes the U.S. Virgin Islands.
3/ Includes corresponding Frasch sulfur data.

TABLE 4
BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES 1/ 2/

(Thousand metric tons, sulfur content, and thousand dollars)

Type of plant	1999	2000
Copper 3/	1,130	830
Zinc 4/	124	123
Lead and molybdenum 4/	70	73
Total	1,320	1,030
Value	$66,400	$55,100

1/ Includes acid produced from imported raw materials.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Excludes acid made from pyrites concentrates.
4/ Excludes acid made from native sulfur.

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TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES 1/ 2/

(Thousand metric tons)

	1999	2000
Total elemental:		
Shipments 3/	9,800	9,500
Exports	685	762
Imports	2,580	2,330
Total	11,700	11,100
Byproduct sulfuric acid:		
Shipments 3/	1,320	1,030
Exports 4/	51	62
Imports 4/	447	463
Grand total	13,400	12,500

1/ Crude sulfur or sulfur content.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes the U.S. Virgin Islands.
4/ May include sulfuric acid other than byproduct.

TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE 1/

(Thousand metric tons, sulfur content)

		Elemental sulfur 2/		Sulfuric acid (sulfur equivalent)		Total	
SIC 3/	End use	1999	2000	1999	2000	1999	2000
102	Copper ores	--	--	726	671	726	671
1094	Uranium and vanadium ores	--	--	8	2	8	2
10	Other ores	--	--	75	44	75	44
26, 261	Pulpmills and paper products	W	W	138	136	138	136
28, 285, 286 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products 4/	116 r/	208	174	152	290 r/	360
281	Other inorganic chemicals	-- r/	--	195	202	195	202
282, 2822	Synthetic rubber and other plastic materials and synthetics	--	--	68	68	68	68
2823	Cellulosic fibers, including rayon	--	--	5	5	5	5
283	Drugs	--	--	3	2	3	2
284	Soaps and detergents	--	W	1	1	1	1
286	Industrial organic chemicals	--	--	90	82	90	82
2873	Nitrogenous fertilizers	--	--	210	213	210	213
2874	Phosphatic fertilizers	--	--	7,770	7,110	7,770	7,110
2879	Pesticides	--	--	19	14	19	14
287	Other agricultural chemicals	1,200	1,260	32	29	1,240	1,290
2892	Explosives	--	--	4	8	4	8
2899	Water-treating compounds	--	--	64	52	64	52
28	Other chemical products	--	--	39	22	39	22
29, 291	Petroleum refining and other petroleum and coal products	1,400	1,460	508	497	1,910	1,960
331	Steel pickling	--	--	13	16	13	16
333	Nonferrous metals	--	--	38	38	38	38
33	Other primary metals	--	--	48	8	48	8
3691	Storage batteries (acid)	--	--	11	11	11	11
	Exported sulfuric acid	--	--	9	6	9	6
	Total identified	2,720	2,790	10,200	9,390	13,000	12,200
	Unidentified	1,100	1,190	185	237	1,290	1,430
	Grand total	3,820	3,980	10,400	9,620	14,300	13,600

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Does not include elemental sulfur used for production of sulfuric acid.
3/ Standard industrial classification.
4/ No elemental sulfur was used in inorganic pigments and paints and allied products.

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TABLE 7
SULFURIC ACID FROM SMELTERS SOLD OR USED IN THE UNITED STATES, BY END USE 1

(Thousand metric tons of 100% H_2SO_4)

SIC 2/	Use	1999	2000
102	Copper ores	2,120	1,950
10	Other ores	W	W
26, 261	Pulp mills and other paper products	W	W
28, 281, 282, 283, 286, 2816	Miscellaneous chemicals	W	W
2873	Nitrogenous fertilizers	W	W
2874	Phosphatic fertilizers	W	W
287, 2879	Pesticides and other agricultural chemicals	100	70
2899	Water-treating compounds	162	W
291	Petroleum refining	W	W
3691	Storage batteries (acid)	W	W
33, 331, 333, 1094	Miscellaneous metal usage	189	62
	Unidentified 3/	865	1,200
	Total	3,440	3,290

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Standard industrial classification.
3/ Includes exports.

TABLE 8
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
Country	Quantity	Value	Quantity	Value
Argentina	(3/)	9	(3/)	3
Australia	18	452	(3/)	6
Brazil	184	5,160	115	3,780
Canada	36	4,160	46	5,300
Colombia	(3/)	79	(3/)	75
India	44	1,160	(3/)	15
Korea, Republic of	6	5,840	5	6,860
Mexico	132	5,020	178	13,100
Morocco	--	--	210	6,040
Senegal	28	847	126	5,910
Other	237	13,100	82	12,600
Total	685	35,800	762	53,700

-- Zero.
1/ Includes exports from the U.S. Virgin Islands.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	133,000	$7,220	154,000	$7,890
China	444	359	5,080	1,240
Dominican Republic	1,830	186	2,760	318
Israel	2,960	815	349	469
Japan	93	120	2,130	324
Korea, Republic of	1	9	45	44
Mexico	1,450	288	3,850	589
Netherlands	66	65	658	104
Netherlands Antilles	509	265	--	--
Panama	--	--	22	13

See footnotes at end of table.

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TABLE 9--Continued
U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Saudi Arabia	2,000	4,150	430	774
Singapore	709	406	777	594
Taiwan	832	452	950	422
Trinidad and Tobago	72	22	4,120	347
United Kingdom	35	85	880	99
Venezuela	190	22	787	90
Other	10,700	2,390	13,300	2,470
Total	155,000	16,800	191,000	15,800

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1999 Quantity	1999 Value 2/	2000 Quantity	2000 Value 2/
Canada	1,640	12,500	1,690	10,900
Mexico	543	27,000	489	19,200
Other	403	12,100	151	9,300
Total	2,580	51,600	2,330	39,400

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Declared customs valuation.

Source: U.S. Census Bureau; as adjusted by the U.S. Geological Survey.

TABLE 11
U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY 1/

Country	1999 Quantity (metric tons)	1999 Value 2/ (thousands)	2000 Quantity (metric tons)	2000 Value 2/ (thousands)
Canada	865,000	$27,100	803,000	$24,300
Germany	69,600	2,100	24,000	926
Japan	162,000	12,200	97,300	6,040
Mexico	107,000	6,810	328,000	8,720
Spain	8,150	245	16,400	478
Other	157,000	14,100	148,000	1,050
Total	1,370,000	62,600	1,420,000	41,500

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Declared c.i.f. (cost, insurance, and freight paid by shipper) valuation.

Source: U.S. Census Bureau.

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TABLE 12
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1996	1997	1998	1999	2000 e/
Australia, byproduct: e/					
Metallurgy	327	474	507	441	654
Petroleum	35	35	35	34 4/	35
Total	362	509	542	475	689
Belgium, byproduct, all sources e/	406	430	428	408	410
Canada, byproduct:					
Metallurgy	1,044	1,072	1,153	1,156	1,200 p/ 4/
Natural gas, petroleum, tar sands	8,446	8,408	8,541	8,960	8,700 p/ 4/
Total	9,490	9,480	9,694	10,116	9,900 p/ 4/
Chile, byproduct, metallurgy e/	587	768	899	1,040	1,100
China: e/					
Elemental	170	200	210	250	250
Pyrites	5,990	6,040	4,490	3,860	3,370
Byproduct, metallurgy	1,100	1,400	1,450	1,580	1,600
Total	7,260	7,640	6,150	5,690	5,220
Finland:					
Pyrites	425	373	430 r/ e/	500 r/ e/	500
Byproduct:					
Metallurgy	291	307	296 e/	300 e/	300
Petroleum	38	50	40 r/ e/	45 e/	50
Total	754	730	766 r/ e/	845 r/ e/	850
France, byproduct: e/					
Natural gas	755	697 4/	600	600	600
Petroleum	235	263 4/	245	250	250
Unspecified	99	100	261	250	260
Total	1,090	1,060	1,110	1,100	1,110
Germany, byproduct: e/					
Metallurgy	20	25	25	25	30
Natural gas and petroleum	1,000	1,085 4/	1,100	1,100	1,110
Unspecified	90	50	50	60	100
Total	1,110	1,160	1,180	1,190	1,240
Iran, byproduct: e/					
Metallurgy	50	50	50	48 r/	50
Natural gas and petroleum	840	850	1,280 r/ 4/	1,302 r/ 4/	1,300
Total	890	900	1,330 r/ 4/	1,350 r/ 4/	1,350
Italy, byproduct: e/					
Metallurgy	216	229	199	193	203
Petroleum	335	380	425	485	490
Total	551	609	624	678	693
Japan:					
Pyrites e/	45	39	23	41	30
Byproduct:					
Metallurgy	1,314	1,331	1,322	1,363	1,400
Petroleum e/	1,790	2,010	2,080	2,060	2,070
Total e/	3,150	3,380	3,430	3,460	3,500
Kazakhstan: e/					
Pyrites	71	--	--	--	--
Byproduct:					
Metallurgy	139	139	212	245	300
Natural gas and petroleum	515	778	933	1,070	1,200
Total	725	917	1,150	1,320	1,500
Korea, Republic of, byproduct: e/					
Metallurgy	260	265	270	280	290
Petroleum	200	200	200	200	200
Total	460	465	470	480	490
Kuwait, byproduct, natural gas and petroleum e/	595	675 4/	665	675	675
Mexico, byproduct:					
Metallurgy	359	417	474	450	450
Natural gas and petroleum	921	923	913	860	860
Total	1,280	1,340	1,387	1,310	1,310

See footnotes at end of table.

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TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1996	1997	1998	1999	2000 e/
Netherlands, byproduct: e/					
Metallurgy	119	127	131	129	84
Petroleum	380	450	432	445	428
Total	499	577	563	574	512
Poland: 5/					
Frasch	1,745 r/	1,673 r/	1,348	1,175	1,369 4/
Byproduct: e/					
Metallurgy	200 r/	256	260 r/	260	260
Petroleum	25	44	57	74	70
Gypsum e/	12 r/	12 r/	10 r/	--	--
Total	1,982 r/	1,985 r/	1,675 r/	1,509 r/	1,700
Russia: e/ 6/					
Native	70	50	50	50	50
Pyrites	400	400	254	300	350
Byproduct, natural gas	3,000	2,950	3,940	4,410	4,900
Other	325	350	411	510	600
Total	3,800	3,750	4,650	5,270	5,900
Saudi Arabia, byproduct, all sources e/	2,300	2,400	2,300	2,400	2,400
South Africa:					
Pyrites	184	167	152 e/	141	146 4/
Byproduct:					
Metallurgy	91	37	100 e/	100 e/	100
Petroleum 7/	232	256	178	164	203 4/
Total	507	460	430	406	448 4/
Spain:					
Pyrites	438	424	430	388	115
Byproduct: e/					
Coal (lignite) gasification	2	2	2	2	1
Metallurgy	428	456	461	455	454
Petroleum	75	85	100	110	115
Total e/	943	967	993	955	685
United Arab Emirates, byproducts, natural gas and petroleum e/	780	967	967	1,089 r/ 4/	1,120
United States:					
Frasch e/	2,900	2,820	1,800	1,780	900
Byproduct:					
Metallurgy	1,430	1,550	1,610	1,320	1,030 4/
Natural gas	2,100	2,420	2,160	2,010	2,020 4/
Petroleum	5,370	5,230	6,060	6,210	6,360 4/
Total e/	11,800	12,000	11,600	11,300	10,300
Uzbekistan, byproduct:					
Metallurgy	145	165 e/	170	175 e/	180
Natural gas and petroleum	250	250 e/	275	280 e/	280
Total	395	415 e/	445	455 e/	460
Venezuela, byproduct, natural gas and petroleum	250	319	425	450	450
Other: e/ 8/					
Frasch	25	20	25	23 r/	24
Native	485	471	463	446	398
Pyrites	552 r/	421 r/	290 r/	227 r/	257
Byproduct:					
Metallurgy	661 r/	606 r/	649 r/	617 r/	677
Natural gas	150	130	206	215	255
Natural gas, petroleum, tar sands, undifferentiated	136 r/	148 r/	156 r/	153 r/	156
Petroleum	490 r/	569 r/	587 r/	540 r/	550
Unspecified	750	810	879	887 r/	888
Total	3,250 r/	3,180 r/	3,250 r/	3,110	3,200

See footnotes at end of table.

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TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1996	1997	1998	1999	2000 e/
Grand total	55,200 r/	57,100	57,100 r/	57,700 r/	57,200
Of which:					
Frasch	4,670 r/	4,510 r/	3,170	2,980	2,290
Native 9/	725	721	723	746	698
Pyrites	8,100 r/	7,860 r/	6,070 r/	5,460 r/	4,770
Byproduct:					
Coal (lignite) gasification e/	2	2	2	2	1
Metallurgy	8,780 r/	9,670 r/	10,200 r/	10,200	10,400
Natural gas	6,000	6,200	6,900	7,230	7,780
Natural gas, petroleum, tar sands, undifferentiated	13,700 r/	14,400	15,300 r/	15,900 r/	15,900
Petroleum	9,210 r/	9,580 r/	10,400 r/	10,600	10,800
Unspecified	3,970	4,140	4,330	4,510	4,660
Gypsum e/	12 r/	12 r/	10 r/	--	--

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 20, 2001.

3/ The term "Source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery, (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch), (3) pyrites (whether or not the sulfur is recovered in the elemental form or as acid), (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers, and (5) recovery from the processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation, where the recovery takes place, which is not the original source country of the crude product from which the sulfur is extracted.

4/ Reported figure.

5/ Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

6/ Sulfur is believed to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

7/ Includes byproduct production from synthetic fuels.

8/ "Other" includes all countries, except the above mentioned: Australia, Belgium, Canada, Chile, China, Finland, France, Germany, Iran, Italy, Japan, Kazakhstan Republic of Korea, Kuwait, Mexico, Netherlands, Poland, Russia, Saudi Arabia, South Africa, Spain, United Arab Emirates, United States, Uzbekistan, and Venezuela.

9/ Includes "China, elemental" and "Iraq, elemental, all sources."

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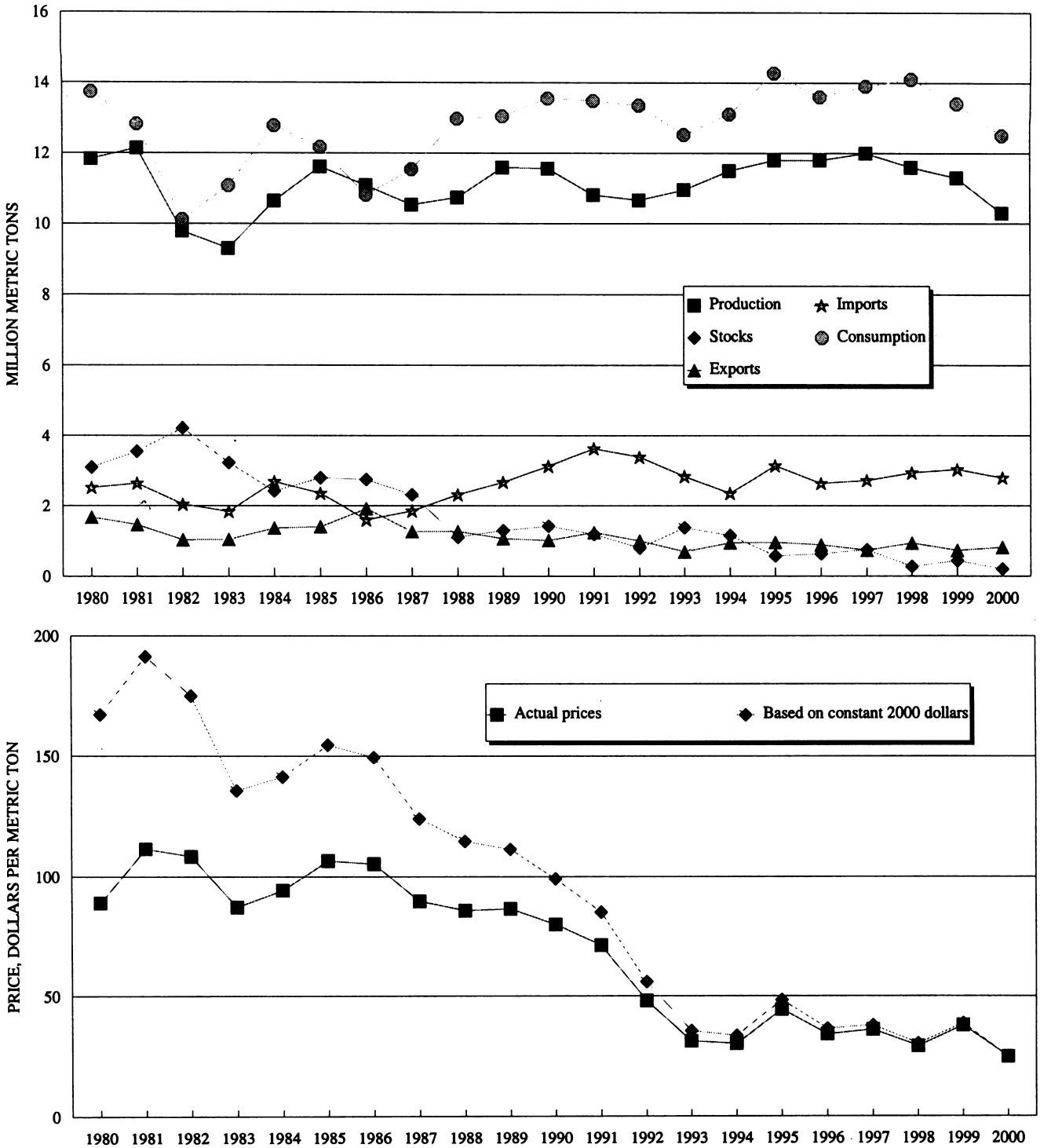
FIGURE 1
TRENDS IN THE SULFUR INDUSTRY IN THE UNITED STATES



Based on the average reported values for elemental sulfur (Frasch and recovered), f.o.b. mine and/or plant, these prices reflect about 90% of the shipments of sulfur in all forms from 1980 through 2000.

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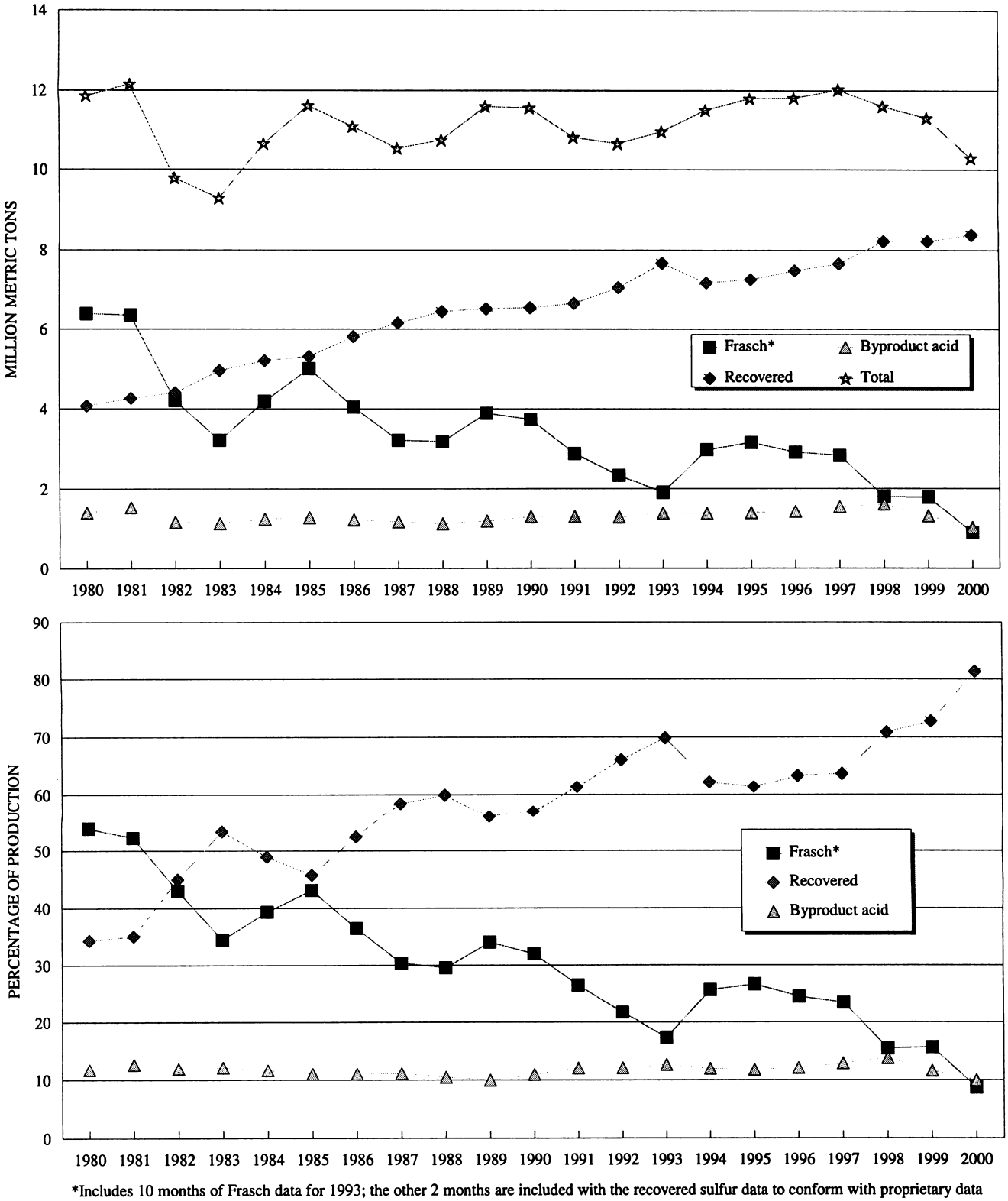
FIGURE 2
TRENDS IN THE PRODUCTION OF SULFUR IN THE UNITED STATES



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to conform with proprietary data requirements. Data are estimates for 1994 through 2000.

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TALC AND PYROPHYLLITE

By Robert L. Virta

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

The mineral talc is a hydrous magnesium silicate. A massive talcose rock is called steatite, and an impure massive variety is known as soapstone. Talc is used commercially because of its fragrance retention, luster, purity, softness, and whiteness. Other commercially important properties of talc are its chemical inertness, high dielectric strength, high thermal conductivity, low electrical conductivity, and oil and grease adsorption. Major markets for talc are ceramics, paint, paper, and plastics.

Pyrophyllite is a hydrous aluminum silicate with a structure similar to talc. Such properties as chemical inertness, high dielectric strength, high melting point, and low electrical conductivity make it useful for ceramic and refractory applications.

Legislation and Government Programs

The National Toxicology Program (NTP) of the U.S. Department of Health and Human Services investigated the possible inclusion of "talc, asbestiform" (talc containing asbestiform fibers) and "talc, nonasbestiform" (talc not containing asbestiform fibers) in the 10th report on carcinogens for Congress. Following its review of the health and mineralogical literature, the NTP subcommittee voted five for and five against listing asbestiform talc as reasonably anticipated to be a human carcinogen in its annual report on carcinogens. Several members of the panel did not feel that human and animal data were sufficient to warrant listing in the report. The vote not to list nonasbestiform talc was seven for and three against. In this case, questions arose about possible asbestos contamination of the talc mentioned in several of the health studies cited. As a result of these votes, the panel recommended against listing asbestiform talc and nonasbestiform talc in its 10th report on carcinogens (U.S. Department of Health and Human Services, Public Health Service, 2001; National Paint and Coatings Association, January 2001, NTP skips over talc, accessed January 8, 2001, at URL http://www.paint.org/ind_issue/current/jan/issue05.htm).

In 2000, the U.S. Department of Defense authorized the disposal of 907 metric tons (t) of block and lump talc, which is the entire uncommitted inventory in that category, from the National Defense Stockpile.

Production

Talc.—In 2000, seven companies operating nine mines in five States produced soapstone, steatite, and talc. All were open pit mines. The producers were, in decreasing order of production, Luzenac America Inc., Wold Minerals Corp. (previously owned by Dal Minerals Co.), Barrett's Minerals Inc., Gouverneur Talc Co., Milwhite Inc., Suzorite Mineral Products Inc. (Zemex Corp.), and Steatite of Southern Oregon. Three other companies, CalTalc Co. in California, Unimin Texas Co. L.P. in Texas, and New World Stone Co. in Virginia worked from stocks. Barrett's Minerals, Gouverneur Talc, Luzenac America, and Wold Minerals were the largest domestic producers, accounting for more than 80% of the tonnage.

In 2000, U.S. mine production was 851,000 t valued at $22.1 million, compared with 925,000 t valued at $26.1 million in 1999 (tables 1 and 2). Production decreased in all States except Texas. Montana led all States in the tonnage and value of talc produced, followed by Texas, Vermont, New York, and Oregon. Mines operating in Montana, New York, Texas, and

Talc and Pyrophyllite in the 20th Century

In 1900, domestic production of talc was about 80,000 metric tons and pyrophyllite production was less than 5,000 tons. Prior to 1900, annual production of talc and pyrophyllite were about 50,000 tons and a few hundred tons, respectively. Talc and pyrophyllite were used interchangeably in the early part of the century. Major markets for milled talc and pyrophyllite were paper and talcum powder. Cut and shaped talc (soapstone) was used for gas tips (nozzles), laboratory benches, laundry tubs, metal worker's talc crayons, sinks, tailor's chalk, tiles, and thermal insulation panels. By the late 1920s, however, many new markets emerged, including ceramics, foundry components, lubricants, paints, roofing, rubber, textiles, and wall plaster. Ceramics, which comprised 1% of talc markets in 1931, accounted for 29% of the market by 1973. During the same time period, sales for paint applications decreased from 48% to 15%, sales for paper decreased from 16% to 7%, sales for refractories increased from 1% to 5%, sales for roofing decreased from 11% to 3%, and sales for rubber decreased from 11% to 3%. Exports accounted for less than 1% of talc sales in 1931 and 15% of sales in 1973. By the 1950s, pyrophyllite had separated itself from talc as a commodity, and its major end-use markets were insecticides (29%), rubber (24%), ceramics (21%), and refractories (13%).

In 2000, domestic production of talc was 851,000 tons, the lowest since 1974. In the past 30 years, talc sales fluctuated between 792,000 tons in 1972 to record high sales of 1.19 million metric tons in 1990. The variations in sales were generally in line with the ups and downs of the U.S. economy. Pyrophyllite production peaked in the early 1960s and then declined through the mid-1980s. Production and sales have been fairly level from the 1980s to the present. In 2000, major domestic talc markets were ceramics (28%), paint (21%), paper (20%), and roofing (8%). Major markets for pyrophyllite were, in decreasing order of consumption, ceramics, refractories, and paint.

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Vermont accounted for nearly all the domestic talc production.

Domestic production data were obtained through a voluntary survey of U.S. mining companies conducted by the U.S. Geological Survey (USGS). Survey forms were sent to 12 companies. Responses accounting for approximately 79% of the data are presented in table 1; the remaining data were estimated from reported prior-year data adjusted according to industry trends.

Pyrophyllite.—Piedmont Minerals Co. Inc. and Standard Mineral Co. Inc. operated three mines in North Carolina and Standard Industrial Minerals Inc. operated one mine in California. Production of pyrophyllite decreased slightly from that of 1999.

Domestic production data were acquired through a voluntary USGS survey of the three U.S. companies that mine pyrophyllite. All responded to the survey.

Consumption

Domestic consumption data for talc and pyrophyllite were developed by the USGS from a voluntary survey of U.S. mills. Survey forms were sent to 13 companies operating 17 mills in 9 States for talc and 3 companies operating 3 mills in 2 States for pyrophyllite. Approximately 81% of the talc data presented in table 3 was reported by the companies; the remaining data were estimated from reported prior-year data adjusted according to industry trends. All the pyrophyllite producers responded to the consumption survey.

Talc.—Approximately 831,000 t of talc valued at $96.1 million was sold or used in 2000, a decrease from 881,000 t valued at $102 million in 1999. Of the 831,000 t of talc sold or used, producers reported that 732,000 t was sold for domestic use and approximately 99,000 t was exported.

Domestic markets included, in decreasing order of consumption, ceramics (sanitaryware, tiles, etc.), paint, paper, roofing, plastics, rubber, cosmetics, and refractories (table 3). Domestic sales of talc declined by 5% in 2000 compared with that of 1999. The slowdown of growth of the domestic economy had an impact on sales in the last half of 2000. Sales of talc to manufacturers of paint, sanitaryware, roofing, and tile are strongly tied to the housing industry. Initiation of new privately owned housing units declined to 1.59 million in 2000 from 1.67 million in 1999. Shipments of architectural paint, the major paint market for talc, declined to 2.52 million liters in 2000 from 2.56 million liters in 1999. Data on sales of vitreous china plumbing fixtures (commodes, sinks, urinals, water tanks, etc.) are not available for 2000, but shipments of fixtures in 1999 were less than those of 1998. Additionally, the difference between production and shipments of vitreous china plumbing fixtures was greater in 1999 than in 1998, suggesting that production in 2000 could be lower than in 1999 to avoid inventory buildup. Despite lower sales of domestically produced talc to manufacturers of plastic products, shipments of plastics have continued to increase. Shipments in 1999 were slightly more than $300 billion compared with $250 billion in 1996. Imports of talc are thought to fill much of the expanding plastics market demand for talc fillers and extenders.

About 75,400 t of talc was reported under the "Other" category by respondents in 2000. Of this amount, 64,500 t was used in animal feed additives, automobile body fillers, caulks, joint compounds, paint and putties, sculpture media, tile flooring, and vinyl sheet flooring. The remainder of the "Other" category (10,900 t) was used in applications that were not identified by respondents.

Most of the imported talc listed in table 6 was not included in the domestic end-use data listed in table 3. Of the 270,000 t of imported talc, approximately 15,000 to 20,000 t was processed and exported. As with 1999, the large tonnage increase in imports probably could not be absorbed in current markets, and about 35,000 to 45,000 t was held in inventory. An estimate of the end-use breakdown based on countries of origin, ports of entry, importing companies, and regional end-use patterns is plastics, 85,000 t; paint, 40,000 t; ceramics and refractories, 20,000 t; paper, 15,000 t; cosmetics, 10,000 t; rubber, 10,000 t; and unknown, 30,000 t.

Pyrophyllite.—Domestic consumption of pyrophyllite was essentially unchanged from that of 1999. Pyrophyllite was used, in decreasing order of consumption, in ceramics, refractories, paint, insecticides, plastics, and rubber. Ceramic and refractory uses accounted for more than 70% of domestic pyrophyllite sales.

Prices

Talc prices varied depending on the quality and the degree and method of processing. The unit value of crude talc was estimated to be $26 per metric ton. More than 85% of the crude ore value included in table 1 was estimated because most talc is sold only after crushing and grinding. Following sorting to remove waste, primary crushing, and screening, the unit value of the unmilled talc probably would be on the order of $50 to $60 per ton, free on board (f.o.b.) at the mill. The average reported unit value of processed talc was $116 per ton, unchanged from that of 1999. The average unit values of crude and processed pyrophyllite decreased slightly from those of 1999.

The average free alongside ship (f.a.s.) unit value for exports of unmilled talc was $236 per ton compared with $114 per ton in 1999. Large fluctuations in pricing can be expected for the low tonnages of crude shipped annually [5,000 to 15,000 metric tons per year (t/yr)]. Additionally, several of the small export shipments have unit values ranging from $700 to $3,552 per ton, suggesting that sculpting-grade talc and talc products such as body powders also may have been included in the export data. The unit value for milled talc exports was $212 per ton in 2000 compared with $195 per ton in 1999. The average Customs unit value for imports was $83 per ton for unground talc (unchanged from 1999), $146 per ton for ground talc ($161 per ton in 1999), and $973 per ton for cut or sawed talc ($932 per ton in 1999).

Approximate prices for talc ranged from $87 to $327 per ton (table 4; Industrial Minerals, 2000d). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer. Three of the larger talc producers in the United States announced price increases to compensate for increased fuel costs associated with minerals mining and processing. Deteriorating profit margins also were cited as contributing to the price increase for Luzenac America. Price increases of 2% to 4% were announced by Minerals Technologies Inc., the parent company of Barrett's Minerals; 5% to 8% by Luzenac America; and 5% to 8% by Zemex Corp., the parent company of Suzorite Mineral Products Inc. (Industrial Minerals, 2000c; North American Minerals News, 2000). Talc producers in Guangxi Province in China

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also announced price increases of up to $2 per ton. The producers cite strong demand and declining reserves in several deposits as the reason for the increase (Industrial Minerals, 2000b).

Foreign Trade

Talc exports increased by 5% in tonnage to 154,000 t and by 21% in value to $32.8 million. Canada was the leading importer of U.S. talc, followed by Venezuela (19,000 t), Belgium, Mexico, Japan, and the Republic of Korea (5,450 t) (table 5). Much of the talc exported to Mexico is shipped to U.S. affiliates operating across the Mexican border and is not reported by the U.S. Census Bureau. Total talc exported across the Mexican border in 2000, including shipments to U.S. affiliates, exceeded 50,000 t.

Talc imports reported by the U.S. Census Bureau increased by 30% in tonnage to 270,000 t and by 20% in value to $42.5 million in 2000. As in 1999, the large increase in imports probably could not be absorbed by talc markets. Some of the imported talc was processed and exported. It is likely that some imported talc was processed and stockpiled for future sales. Announced price increases on some of the Chinese talc may have prompted some importers to make larger than normal purchases before the price changes took effect. Canada, China, and Japan supplied 78% of all talc imports (table 6). Most of the talc imported from Japan was likely to have been transshipments from other Southeast Asian countries or from Australia.

Approximately 36% (98,100 t) of talc imported into the United States came through the customs district of New Orleans, LA, almost all of which was unmilled. Of this amount, 89,900 t was imported from China, 8,000 t from Australia, and 236 t from France. The second leading customs district was Houston, TX, with 38,900 t (mainly unmilled talc from China and France), followed by New York, NY, with 34,400 t (mainly milled talc from Japan and Italy); Detroit, MI, with 31,700 t (mainly from Canada); Charleston, SC, with 18,200 t (milled talc mainly from Italy); Duluth, MN, with 13,300 t (milled talc from Canada); and Buffalo, NY, with 10,200 t (milled talc mainly from Canada). The remaining imports were dispersed among the many other customs districts.

World Review

China remained the world's leading producer of talc, followed by the United States, India, Finland, France, and Brazil. The Republic of Korea was the largest producer of pyrophyllite, followed by Japan and Brazil. China, Japan, the Republic of Korea, and the United States produced 61% of the world's talc and pyrophyllite (table 7).

Australia.—WMC Resources Ltd. sold its 50% share of Mondo Minerals Oy to Omya plc. Mondo Minerals was a consolidation of Finnminerals Oy and WMC's Westmin Talc BV. It was operated as a 50-50 joint venture with Omya. WMC still owns the Three Springs talc mine in Western Australia but has decided to sell that operation as well. The company had just inaugurated its new $11 million micronizing mill in October. WMC's Three Springs operation produces micronized talc for the paint, paper, plastics, and technical ceramics markets (Industrial Minerals, 2000e).

Poland.—Rozmin s.r.o. began studying proposals for mine construction at its Gemerska Poloma talc deposit in eastern Slovakia. The company anticipated production to begin in mid-2000 at a rate of 80,000 t/yr. The deposit contains an estimated 16 million metric tons of reserves. Rozmin will jointly market the talc with Gebrueder Dorfner GmbH and Co., a German marketing company. The talc will be sold for paint, paper, plastic, and rubber applications (Industrial Minerals, 2000a).

Outlook

While still strong, sales of talc have declined slightly over the past 2 years. An economy that began slowing in early to mid-2000 has contributed to the decline and does not bode well for 2001. Major markets for talc, such as ceramics, paint, and paper, which were projected to grow through 2003, probably will begin to level off. This mirrors a decline in new housing units being built; new home construction uses many products that contain talc. Plastics still offer the greatest opportunity for expansion. Imports will continue to play a larger role in the U.S. talc market, particularly in the plastics markets. No major changes are anticipated in pyrophyllite markets, and consumption probably will not change significantly for the next few years.

References Cited

Industrial Minerals, 2000a, Gemerska Poloma talc deposit development: Industrial Minerals, no. 396, September, p. 19.

———2000b, Guangxi talc prices rising: Industrial Minerals, no. 398, November, p. 86.

———2000c, Luzenac talc price increases: Industrial Minerals, no. 398, November, p. 73.

———2000d, Prices: Industrial Minerals, no. 399, December, p. 75.

———2000e, WMC withdraws from talc as Omya gains Mondo Minerals: Industrial Minerals, no. 399, December, p. 8.

North American Minerals News, 2000, Luzenac raises talc for 2001 as energy costs bite: North American Minerals News, no. 67, December, p. 7.

U.S. Department of Health and Human Services, Public Health Service, 2001, National Toxicology Program—Call for public comments on 8 nominations proposed for listing in or delisting from the report on carcinogens, 10th edition: Federal Register, v. 66, no. 43, March 5, p. 13334-13338.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Greene, R.C., 1995, Talc resources of the conterminous United States: Open-File Report OF 95-586.

Talc. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Talc and Pyrophyllite. Ch. in Mineral Commodity Summaries, annual.

U.S. Talc—Baby Powder and Much More. Fact Sheet FS-065-00, 2000.

Other

Ceramic Industry.

Engineering and Mining Journal.

Mining Engineering.

Paint and Coatings Industry.

Talc and Pyrophyllite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

The Talc Industry—An Overview. U.S. Bureau of Mines Information Circular 9220, 1989.

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TABLE 1
SALIENT TALC AND PYROPHYLLITE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Mine production, crude:					
Talc	994	1,050	971	925	851
Pyrophyllite	W	W	W	W	W
Total	994	1,050	971	925	851
Value:					
Talc	31,100	33,000	27,300	26,100	22,100
Pyrophyllite	W	W	W	W	W
Total	31,100	33,000	27,300	26,100	22,100
Sold by producers, crude and processed:					
Talc	909	942	870	881	831
Pyrophyllite	W	W	W	W	W
Total	909	942	870	881	831
Value:					
Talc	100,000	111,000	109,000	102,000	96,100
Pyrophyllite	W	W	W	W	W
Total	100,000	111,000	109,000	102,000	96,100
Exports (talc) 2/	192	179	146	147	154
Value	37,900	34,200	26,000	27,200	32,800
Imports for consumption	187	123	165	208	270
Value	20,500	21,100	23,300	35,300	42,500
Apparent consumption 3/	989	994	990	986	967
World, production	9,880	11,100 r/	10,100 r/	10,000 r/	9,640 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes powders--talcum (in package), face, and compact.
3/ Production plus imports minus exports plus adjustments in Government and industry stock. Does not include pyrophyllite.

TABLE 2
CRUDE TALC PRODUCED IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
State	Quantity	Value	Quantity	Value
Texas	220	5,000	230	3,940
Other 3/	705	21,100	620	18,100
Total	925	26,100	851	22,100

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes pyrophyllite.
3/ Includes California, Montana, New York, Oregon, and Vermont.

TABLE 3
END USES FOR GROUND TALC 1/ 2/

(Thousand metric tons)

	1999	2000
Ceramics	209	205
Cosmetics	27	21
Insecticides	8	2
Paint	142	152
Paper	167	145
Plastics	64	39
Refractories	2	5
Roofing	60	58
Rubber	19	30
Other 3/	73	75
Total	771	732

See footnotes at end of table.

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TABLE 3--Continued
END USES FOR GROUND TALC 1/ 2/

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes pyrophyllite.
3/ Includes art sculpture, asphalt filler, auto body filler, construction caulks, flooring, joint compounds, and other uses not specified.

TABLE 4
PRICES OF TALC

(Dollars per metric ton)

	Price
New York:	
Paint:	
200 mesh	104
400 mesh	187
Ceramic:	
200 mesh	87
325 mesh	97
Italian, cosmetic-grade	248
Chinese, normal (ex-store):	
UK 200 mesh	284-320
UK 350 mesh	298-327

Source: Industrial Minerals, December 2000.

TABLE 5
U.S. EXPORTS OF TALC 1/ 2/

(Thousand metric tons and thousand dollars)

	1999		2000	
Country	Quantity	Value	Quantity	Value
Belgium	14	1,780	9	1,830
Canada 3/	55	9,910	58	9,920
Japan	7	1,250	7	1,300
Mexico	17	1,780	8	966
Other 4/	54	12,500	72	18,800
Total	147	27,200	154	32,800

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes powders--talcum (in package), face, and compact.
3/ Probably includes shipments in transit through Canadian ports.
4/ Includes 47 countries in 1999 and 52 countries in 2000.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF TALC, BY COUNTRY 1/

	Not crushed or powdered		Crushed or powdered		Cut and sawed		Total unmanufactured	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:								
Brazil	2	$5	75	$19	1,230	$1,070	1,310	$1,090
Canada	89	37	44,100	11,400	6,220	4,980	50,400	16,500
China	91,900	7,380	1,070	251	579	387	93,500	8,020
France	175	235	21,300	384	5,060	5,180	26,600	5,800
Japan	--	--	15,100	869	6	19	15,100	888
Other 2/	20,000	1,600	892	357	508	1,040	21,400	3,000
Total	112,000	9,260	82,600	13,300	13,600	12,700	208,000	35,300

See footnotes at end of table.

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TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF TALC, BY COUNTRY 1/

Country	Not crushed or powdered Quantity (metric tons)	Not crushed or powdered Value (thousands)	Crushed or powdered Quantity (metric tons)	Crushed or powdered Value (thousands)	Cut and sawed Quantity (metric tons)	Cut and sawed Value (thousands)	Total unmanufactured Quantity (metric tons)	Total unmanufactured Value (thousands)
2000:								
Brazil	80	3	121	19	663	589	864	611
Canada	261	113	58,100	14,300	7,820	6,420	66,200	20,900
China	121,000	9,870	1,120	346	837	723	123,000	10,900
France	7,010	752	474	429	4,580	4,750	12,100	5,930
Japan	--	--	21,900	1,020	214	259	22,100	1,280
Other 2/	14,800	1,070	31,100	345	447	1,480	46,300	2,890
Total	143,000	11,800	113,000	16,500	14,600	14,200	270,000	42,500

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes 18 countries in 1999 and 26 countries in 2000.

Source: U.S. Census Bureau.

TABLE 7
TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Argentina:					
Pyrophyllite	2,180	4,242 r/	3,450 r/	4,000 e/	4,000
Steatite e/	300	300	300	300	300
Talc	11,777	13,380	14,585 r/	14,600 r/ e/	14,600
Australia: e/					
Pyrophyllite	5,000	5,000	5,000	5,000	10,000
Talc	210,000	210,000	210,000	210,000	250,000
Austria, steatite e/	130,000	155,730 4/	156,000	150,000	150,000
Brazil, unspecified e/ 5/	452,180 4/	452,000	452,000	452,000	452,000
Canada, pyrophyllite, soapstone, talc	77,000	73,000	78,000	79,000 e/	79,000
Chile, talc	4,276	3,986	3,772	3,800 e/	3,850
China, unspecified e/	4,000,000	4,100,000	3,800,000	3,900,000	3,500,000
Colombia, pyrophyllite, soapstone, talc e/	14,800	14,832 4/	15,000	15,000	15,000
Egypt, pyrophyllite, soapstone, steatite, talc	41,227	43,627	39,720	40,000 e/	40,000
Finland, talc e/	345,000 4/	350,000	350,000	350,000	360,000
France, crude talc e/	349,270 4/	350,000	325,000	350,000	350,000
Germany, talc (marketable)	10,005	8,819	15,473	15,000 e/	15,000
Guatemala, talc e/	694 4/	700	700	750	740
Hungary, talc e/	1,200	1,200	1,200	1,200	1,200
India:					
Pyrophyllite	143,172	121,566	79,951	85,000 e/	85,000
Steatite	472,001	417,613	447,550	450,000 e/	460,000
Iran, talc e/ 6/	20,000	20,000	20,000	20,000	20,000
Italy, steatite and talc e/	168,000	142,000	140,000	140,000	140,000
Japan:					
Pyrophyllite	913,973	913,822	764,079	694,317 r/	692,998 4/
Talc e/	56,153 4/	53,000	50,000	50,000	50,000
Korea, North, unspecified e/	180,000	180,000	150,000	120,000	120,000
Korea, Republic of:					
Pyrophyllite	780,062	994,366	843,609	754,657 r/	760,000
Talc	19,066	25,751	24,411	15,313 r/	16,000
Macedonia, talc e/	10,000	10,000	10,000	10,000	10,000
Mexico, talc	10,100	13,586	18,843	18,981 r/	19,000
Morocco	13,053	19,850	20,000	20,000 e/	20,000
Nepal, talc 7/	5,323	6,809	5,553 r/	5,400 r/ e/	5,500
Norway, talc e/	28,000 r/	28,000 r/	26,000 r/	26,000	27,000
Pakistan, pyrophyllite	34,095	45,414	48,927	67,670 r/	70,000
Paraguay, unspecified e/	200	200	200	200	200

See footnotes at end of table.

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TABLE 7--Continued
TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons)

Country 3/	1996	1997	1998	1999	2000 e/
Peru: e/					
Pyrophyllite	8,000	8,000	8,000	8,000	8,000
Talc	12,985 4/	13,000	13,000	13,000	13,000
Portugal, talc	8,277	8,236	8,400 e/	8,400 e/	8,000
Romania, talc	10,248	7,578	8,134 r/	8,289 r/	8,200
Russia, talc e/	100,000	90,000	79,000 r/	90,000	100,000
South Africa:					
Pyrophyllite	8,837 r/	10,610 r/	11,500 r/	13,277 r/	12,173 4/
Talc	9,700 r/	12,600 r/	11,300 r/	7,900 r/	5,600 4/
Spain, teatite e/	109,756 4/	110,000	110,000	110,000	100,000
Sweden, talc e/	30,000 4/	25,000	25,000	25,000	26,000
Taiwan, talc	1,500	1,331	73	201 r/	200
Thailand:					
Pyrophyllite	64,330	304,524	40,241	42,000 e/	40,500
Talc	7,238	7,139	2,172 r/	2,000 e/	2,000
Turkey e/	4,000	4,000	5,000	5,000	5,000
United Kingdom, pyrophyllite, soapstone, talc e/	5,322 4/	5,500	5,000	5,000	5,000
United States:					
Pyrophyllite	W	W	W	W	W
Talc	994,000	1,050,000	971,000	925,000	851,000 4/
Uruguay, pyrophyllite, soapstone, talc	898	1,133	972	2,905 r/	1,000
Zambia, talc e/	80	80	80	80	80
Zimbabwe, talc	1,076	1,023	1,039	1,000	1,000
Grand total	9,880,000	11,100,000 r/	10,100,000 r/	10,000,000 r/	9,640,000
Of which:					
Pyrophyllite	1,960,000 r/	2,410,000 r/	1,800,000 r/	1,670,000 r/	1,680,000
Steatite	712,000	684,000	714,000	710,000	710,000
Talc	2,260,000	2,310,000 r/	2,190,000 r/	2,170,000 r/	2,160,000
Unspecified	4,960,000	5,720,000 r/	5,420,000 r/	5,490,000 r/	5,090,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Totals."

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 24, 2001.

3/ In addition to the countries listed, the former Czechoslovakia produces talc, but information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ As reported in the Sumário Mineral 1999-2000.

6/ Data based on Iranian fiscal year beginning March 21 of year stated.

7/ Data based on Nepalese fiscal year beginning mid-July of year stated.

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THORIUM

By James B. Hedrick

Domestic survey data and tables were prepared by Jason T. Collins, statistical assistant, and the world production tables were prepared by Ronald L. Hatch, lead international data coordinator.

Thorium is the second member of the actinide series of elements in the periodic table. As a pure metal, it is a soft, very ductile, heavy, silver-gray metallic element. It is represented by the chemical symbol Th and several isotopic symbols, the most common being, thorium-232 (Th^{232}). Thorium metal has a very high melting point at 1,750° C. The oxide, which is also called thoria, has the highest melting point of all the binary oxides at about 3,300° C. Th^{232} is the most abundant of the four naturally occurring isotopes of thorium. Th^{232} emits radioactive alpha particles and has a very long half-life of 1.405×10^{10} years. Daughter products created by the radioactive decay of Th^{232} emit alpha, beta, and gamma emissions. Most products of the disintegration series have short half-lifes, ranging from 5.75 years to 0.145 second. The final decay product of the Th^{232} series is the stable isotope Pb^{208}. Thorium's other naturally occurring isotopes (typically uranium decay products), Th^{228}, Th^{230}, and Th^{234}, have half-lifes of 1.9116 years, 75,380 years, and 24.1 days, respectively.

Thorium was discovered in 1828 by Swedish chemist and mineralogist Jöns Jakob Berzelius (Söderbaum, 1929). He named it "thoria," after Thor, the ancient Norse god of thunder. Berzelius isolated the element from a black silicate mineral from the island of Lövö near Brevig, Norway (Weeks and Leicester, 1968, p. 532). Subsequently, the black mineral from which thoria was derived was named thorite. In 1898, thorium's radioactivity was discovered independently by Marie S. Curie (Curie, 1928) and Gerhard C. Schmidt (Badash, 1966).

At 7.2 parts per million, thorium is the 39th most abundant of the 78 common elements in the Earth's crust. It is about three times more abundant than uranium and is associated with uranium in igneous rock. Because the primary thorium minerals are more resistant to geochemical and physical weathering, the thorium-to-uranium ratio in sedimentary rock is typically higher than its ratio in igneous source rock. Thorium occurs in several minerals, the most common being the rare earth thorium-phosphate mineral monazite, the thorium silicate minerals thorite (Berzelius, 1829) and huttonite (Pabst, 1951), and the hydrated thorium silicate mineral thorogummite (Hidden and Mackintosh, 1889, p. 480-481).

Domestic consumption of refined thorium products decreased substantially in 2000 (table 1). The value of thorium metal and compounds used by the domestic industry was estimated to be about $285,000. Thorium and its compounds were produced primarily from monazite recovered as a byproduct of processing heavy-mineral sands for titanium and zirconium minerals or for tin minerals. Monazite was recovered primarily for its rare-earth content, and only a small portion of the thorium produced was consumed. The major monazite-producing countries were Brazil, India, Malaysia, and Sri Lanka. All thorium compounds, metal, and alloys used by the domestic industry were derived from imports, company stocks, or material previously sold from U.S. Government stocks.

Limited demand for thorium, relative to the rare earths, continued to create a worldwide oversupply of thorium compounds and residues. Most major rare-earth processors have switched feed materials to thorium-free intermediate compounds, such as rare-earth chlorides, nitrates, or hydroxides. Excess thorium not designated for commercial use was either disposed of as a radioactive waste or stored for potential use as a nuclear fuel or other application. Principal nonenergy uses have shifted from refractory applications to welding electrodes, chemical catalysts, and lighting.

Problems associated with thorium's natural radioactivity represented a significant cost to companies involved in its

Thorium in the 20th Century

In 1900, thorium brightened the world by providing light in the form of brilliant white incandescent lamp mantles. Thorium was derived entirely from the mineral monazite, which was mined for both the oxides of the rare earths and the thorium it contained. At the turn of the last century, 412 metric tons of monazite valued at $48,805 were produced in North Carolina. Most of the monazite produced domestically was exported to Germany and Austria for the manufacture of lamp mantles. Domestic demand for thorium-bearing monazite increased in 1900 when the competing deposits in Brazil came under the control of a single group, and the price of thorium increased. The use of thorium in lamp mantle manufacture was its only commercial application at the start of the 20th century and accounted for 92% of its nonfuel use in 1950. Large demand for thorium, however, had started dimming by 1912 as the gas mantle was largely replaced in the home by incandescent electric light.

In 2000, thorium was no longer produced in the United States and most other parts of the world because of concerns about its naturally occurring radioactivity. The real and potential costs related to compliance with State and Federal regulations, proper disposal, legal liability, and monitoring of its radioactivity have severely limited thorium's commercial value. Most major domestic thorium consumers switched to nonradioactive substitutes in the 1990s. Monazite production in the United States ceased at the end of 1994 owing to decreased demand for thorium-containing ores. Principal uses for thorium in 2000 were in welding electrodes, chemical catalysts, high-temperature refractory applications, incandescent lamp mantles, traveling wave tubes, and microwave-emitting magnetron tubes for radar and microwave ovens.

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mining, processing, manufacture, and use. Increased costs to comply with environmental regulations, to deter potential legal liabilities, and to purchase storage and waste disposal space were the principal deterrents to its commercial use. Concern of the effect of thorium's natural radioactivity on health has not been a significant factor in switching to alternative nonradioactive materials.

Legislation and Government Programs

The National Defense Authorization Act for Fiscal Year 2000 (Public Law 106-65), which was enacted on October 5, 1999, did not change the previous authorization for the disposal of all stocks of thorium nitrate in excess of the National Defense Stockpile (NDS) goal of 272,155 kilograms (kg) (600,000 pounds). The law authorized the transfer of no more than $150 million from the NDS transaction fund to the operation and maintenance accounts (no more than $50 million each) of the Army, Navy, and Air Force (section 304). The law also obligated no more than $78.7 million of the NDS transaction fund for the operation of the NDS program, including disposal of hazardous materials that are environmentally sensitive, which would include thorium.

The Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (Public Law 106-398), which was enacted on October 30, 2000, continued the funding of $150 million ($50 million each) of the operation and maintenance accounts of the Army, Navy, and Air Force by the NDS transaction fund. The law obligated no more than $71 million of the NDS transaction fund for the operation of the NDS program, including disposal of hazardous materials that are environmentally sensitive, a decrease of $7.7 million from the previous fiscal year. The revised annual material plan for fiscal year 2000 authorized the disposal of 2,946,033 kg (6,494,891 pounds) of thorium nitrate from the NDS classified as excess to goal.

Production

Domestic mine production data for thorium-bearing minerals were developed by the U.S. Geological Survey from a voluntary survey of U.S. thorium operations. The survey form was sent to one mine, the only previously producing thorium-bearing monazite mine still in operation and it responded. Although thorium was not produced in the United States in 2000, the mine that had previously produced thorium-bearing monazite continued to operate and maintained capacity on standby. Monazite was last produced in the United States in 1994.

Essentially all thorium alloys and compounds used by the domestic industry were derived from imports, company stocks, or materials sold from the NDS. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as lighting, chemical catalysts, and welding electrodes.

Consumption

Statistics on domestic thorium consumption were developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments.

Domestic thorium producers reported consumption of 6 metric tons (t) of thorium oxide equivalent in 2000, a decrease from the 7 t consumed in 1999 (table 1). Nonenergy uses accounted for almost all domestic consumption.

Because of the high melting point of thorium oxide it was used in several refractory applications. High-temperature uses were in ceramic parts, investment molds, and crucibles.

Thorium nitrate was used overseas in the manufacture of lamp mantles for use in incandescent camping lanterns, and natural gas and oil lamps. Thorium mantles provide an intense white light that can be adjusted towards the yellow region by the addition of a small amount of cerium. Thoriated mantles have not been produced domestically since the development of a suitable thorium-free substitute, a proprietary yttrium-based mixture.

Thorium nitrate was also used to produce thoriated tungsten welding electrodes. These electrodes were used to join stainless steels, nickel alloys, and other alloys requiring a continuous and stable arc to achieve precision welds.

The nitrate form was also used to produce thoriated tungsten elements used in the negative poles (cathodes) of magnetron tubes and traveling wave tubes, also known as TWTs. Thorium was used because of its ability to emit free electrons at ambient temperatures when heated in a vacuum. With an improved work function and lower operating temperature, thoriated cathodes lasted longer than nonthoriated filaments. Magnetron tubes were used microwave ovens and to emit electrons at microwave frequencies in radar systems for air traffic control, surveillance, weather monitoring, and weapon systems.

Other applications of thorium included chemical catalysts, electron-emitting tubes, special-use light bulbs, fuel cells, high-refractivity glass, photoconductive films, radiation detectors, and target materials for x-ray tubes.

In metallurgical applications, thorium had been used as an alloy with other metals, primarily magnesium. Magnesium-thorium alloys were used by the aerospace industry for their lightweight, high strength, and excellent creep resistance at elevated temperatures. Thorium-free magnesium alloys with similar properties have been developed and have replaced most of the thorium-magnesium alloys. Small quantities of thorium were used in dispersion-hardened alloys for high-strength, high-temperature applications, because thorium metal has a high melting temperature of 1,750° C and a boiling point of about 4,790° C.

Thorium was used as a nuclear fuel in the Th^{232}/U^{233} fuel cycle. No foreign or domestic commercial reactors were operating with this fuel cycle; however, thorium was being tested as a fuel component in Russia.

Stocks

Government stocks of thorium nitrate in the NDS were 3,218,177 kg (7,094,865 pounds) on December 31, 2000. The NDS inventory included 273,181 kg (602,262 pounds) of containerized thorium nitrate allocated to meet the NDS goal requirements and 2,944,995 kg (6,492,603 pounds) classified as excess to the goal. No stocks of thorium nitrate were sold or shipped during the year, the NDS, however, received additional stocks of 1,349 kg (2,974 pounds) of thorium nitrate.

The U.S. Department of Energy (DOE) inventory at yearend

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2000 was 182,000 kg of thorium oxide equivalent contained in metal and various compounds. The DOE contractor, Fernald Environmental Restoration Management Co., which is a division of the Fluor Corp. subsidiary Fluor Daniel Inc., shipped 353 t of thorium oxide to Nevada for disposal during the year.

Prices

The price of monazite concentrate (typically sold with a minimum 55% rare-earth oxide content, including thorium oxide), free-on-board (f.o.b.) as quoted in U.S. dollars and based on 1997 U.S. import data, remained unchanged at $400.00 per metric ton. In 2000, no monazite was imported into the United States.

Thorium oxide prices in 2000, quoted by Rhodia, Inc., were unchanged from the previous year's level. At yearend, thorium oxide prices per kilogram f.o.b. Shelton, CT, were $82.50 for 99.9% purity and $107.25 per kilogram for 99.99% purity. Thorium nitrate prices from Rhodia were $27.00 per kilogram for mantle-grade material.

World Review

Thorium demand continued to remain depressed as industrial consumers expressed concerns about the potential liabilities, the cost of complying with environmental monitoring and regulations, and the cost increases at approved waste disposal sites.

Current Research and Technology

Radkowsky Thorium Power Corp. (RTPC) received its fourth and final U.S. patent for its nonproliferative seed-and-blanket fuel assembly. The patent was issued to inventor Alvin Radkowsky and the assignee, RTPC. The invention details an improved seed-blanket reactor, which can provide optimum operation from an economic and a nonproliferative perspective. An additional objective is to provide a reactor design that uses large quantities of plutonium and thorium without generating proliferative waste byproducts (U.S. patent No. 6,026,136, issued February 15, 2000).

In July, the Kurchatov Institute obtained a license from the Russian Nuclear Regulatory Committee to begin testing the Radkowsky-designed thorium fuel. An additional 35 scientists at the Kurchatov Institute in Russia were assigned to work with the Radkowsky thorium fuel team. Fuel irradiation experiments began by testing the thorium fuel ampoules in an IR-8 reactor (Thorium Power, July 2000, Thorium power—2000, accessed January 5, 2001, at URL http://www.thoriumpower.com/whats_new/2000.html).

Outlook

Thorium's use in the United States has decreased substantially during the past decade. Domestic demand is forecast to remain at 2000 depressed levels unless low-cost technology is developed to dispose of residues or its use as a nonproliferative nuclear fuel gains widespread commercialization. Its future use in nonenergy applications is expected to continue as a chemical catalyst. Manufacturers have successfully developed acceptable substitutes for thorium-containing incandescent lamp mantles, paint and coating evaporation materials, magnesium alloys, ceramics, and investment molds. The traditionally small markets for domestic thorium compounds, chemical catalysts, welding electrodes, and lighting are expected to remain the leading consumers of thorium compounds through the next decade and longer.

The potential for growth in the applications of thorium in nonenergy applications is limited by its natural radioactivity. Its greatest potential exists in energy applications as a nuclear or a subatomic fuel in industries that accept radioactivity. In the long term, however, high disposal costs, increasingly stringent regulations, and public concerns related to thorium's natural radioactivity are expected to continue to depress its future use in nonenergy applications, especially in the United States.

References Cited

Badash, Lawrence, 1966, The discovery of thorium's radioactivity: Journal of Chemical Education, v. 43, p. 219-220.

Berzelius, J.J., 1829, Undersökning af ett nytt mineral (Thorit), som innehåller en förut obekant jord [Investigation of a new mineral (thorite), as contained in a previously unknown earth (oxide)]: Kungl. Svenska Vetenskapsakademien Handlingar, p. 1-30.

Curie, M.S., 1928, Classic of science—Radioactive substances by Madame Curie: Science News Letter, v. 14, p. 137-138.

Hidden, W.E., and Mackintosh, J.B., 1889, A description of several yttria and thoria minerals from Llano County, Texas: American Journal of Science, 3d series, v. 38, no. 228, December, p. 474-486.

Pabst, Adolf, 1951, Huttonite—A new monoclinic thorium silicate: American Mineralogist, v. 36, p. 60-69.

Söderbaum, H.G., 1929, Jac. Berzelius levnadsteckning [Jacob Berzelius—A portrait of his life]: Uppsala, Sweden, Almquist & Wiksells Boktryckeri A-B, v. 2, p. 66-68.

Weeks, M.E., and Leicester, H.M., 1968, Discovery of the elements (7th ed.): Easton, PA, Journal of Chemical Education, 896 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Nuclear Fuels. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Thorium. Mineral Industry Surveys, annual.
Thorium. Ch. in Mineral Commodity Summaries, annual.
Thorium. Ch. in Minerals Yearbook, annual.

Other

Thorium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Uranium Industry Annual. U.S. Department of Energy, 1997.

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TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS 1/

(Kilograms of thorium dioxide, unless otherwise specified)

		1996	1997	1998	1999	2000
Exports, compounds		58	241	1,130	2,520	4,640
Imports:						
Thorium ore, including monazite		7,070	1,400	--	--	--
Compounds		26,400	13,500	7,450	5,290	11,100
Shipments from Government stockpile excesses		--	--	--	--	--
Consumption, reported nonenergy applications 2/		4,920	13,000	7,000	7,000	6,000
Prices, yearend						
Nitrate 3/	dollars per killogram	$14.32	$27.00	$27.00	$27.00	$27.00
Oxide 4/	do.	$64.45	$82.50	$82.50	$82.50	$82.50

-- Zero.

1/ Data are rounded to no more than three significant digits, except prices.

2/ All domestically consumed thorium was derived from imported metals, alloys, and compounds.

3/ Source: Rhodia Canada, Inc., f.o.b. port of entry, duty paid, ThO_2 basis

4/ Source: Rhodia Electronics and Catalysis, Inc., 99.9% purity.

TABLE 2
U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS 1/

(Kilograms and dollars)

	1999		2000		
	Quantity	Value	Quantity	Value	Principal destinations/sources and quantities, 2000
Exports, compounds	2,520	318,000	4,640	478,000	Panama 2,000; Canada 1,600; Japan 494.
Imports, compounds	5,290	280,000	11,100	528,000	France 11,100; Switzerland 26.

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

TABLE 3
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1996	1997	1998	1999	2000 e/
Brazil e/	-- r/	460 r/	-- r/	-- r/	--
India e/	5,000	5,000	5,000	5,000	5,000
Malaysia	618	767	517 r/	1,147 r/	1,000
Sri Lanka e/	200	200	200	200	200
Thailand	--	12	--	--	--
Total	5,820	6,440	5,720	6,350	6,200

e/ Estimated. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 18, 2001.

3/ In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and countries of the former U.S.S.R. may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.

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TIN

By James F. Carlin, Jr.

Domestic survey data and tables were prepared by Elsie D. Isaac, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

Tin was not mined in the United States during 2000. Twenty-five firms consumed 86% of reported primary tin used domestically. The major uses were as follows: electrical, 24%; cans and containers, 21%; transportation, 14%; construction, 11%; and others, 30%. The estimated value of primary metal consumed domestically was about $310 million. Industry stocks remained steady (tables 2 and 4).

About 17,600 metric tons (t) of tin in old and new scrap, including tin alloys, were recycled (table 5); of this about 6,600 t was old scrap. Almost one-fifth of the tin consumed in the United States was produced at 4 detinning plants and 45 secondary nonferrous-metal processing plants. Interest remained strong in the recycling of used tin cans, partly because of rising fees and limited space at landfills. The recycling rate for steel cans was 58% in 2000, compared with 58% in 1999, 56% in 1995, and 15% in 1988.

The Defense Logistics Agency (DLA), which manages the National Defense Stockpile (NDS), sold 12,000 t of pig tin from the stockpile during 2000. At yearend, 59,686 t remained in the stockpile.

World tin mine output increased by 10% (tables 1 and 9). Industry observers believed that world supply and demand were in approximate equilibrium. World tin smelter production increased by 2%. The average Platt's Metals Week composite price for tin rose by 1%.

Of the 22 countries in which tin was mined, the top 6 accounted for 91% of the world total of 238,000 t. China was the largest producer (41% of the world total) and was followed by Indonesia (20%), Peru (16%), Brazil (5%), Bolivia (5%), and Australia (4%) (table 9).

World tin reserves, estimated to be 8 million metric tons (Mt), were considered to be adequate to meet the world's future tin requirements. Assuming that world primary tin consumption will be about 200,000 metric tons per year (t/yr), these reserves would last 38 years. Most tin reserves are in Asia and South America.

Legislation and Government Programs

In 2000, the DLA sold 12,000 t of pig tin in the NDS to two companies. Both sales were long-term contracts allowing for deliveries of the tin over a 1-year period. Spot market sales of tin ended in 1999. The effect of NDS tin sales on domestic markets is assessed by the Market Impact Committee, composed of several Federal Agencies, including the U.S. Geological Survey (USGS). The NDS tin is stored at Government sites in Hammond, IN; Baton Rouge, LA; Point Pleasant, WV; and New Haven, IN. At yearend, the remaining unsold inventory was 59,686 t.

Production

Mine.—Tin was not produced at any U.S. mine in 2000. Until 1993, a few small tin mines had operated sporadically in the United States for many years. However, USGS canvasses confirm that there has been no domestic tin production since that year.

Secondary.—Industry observers believe the United States is the world's largest producer of secondary tin. Most secondary

Tin in the 20th Century

In 1900, the United States was the world's major tin user. Domestic tin production was modest and came mostly from Alaska. The Nation depended almost entirely on tin imports for its needs. Over 80% of the tin imported came from Malaysia, which was the world's dominant tin producer at the time. Statistics are not available, but there is evidence that solder and tinplate were the major domestic uses for tin, with bronze and tinning next in importance. In 1900, all tinplate was made by the hot-dip process on cut-length sheets. The electrolytic tinplate process was developed in Germany in the late 1930s, under the impetus of accelerated production needed for Germany's war effort. By the early 1940s, the high-speed electrolytic process took hold in the United States, and by the mid-1960s hot-dipping was phased out. In 1939, tin became the first material purchased for a U.S. Government stockpile established for wartime use. From the late 1940s through the early 1950s, acquisitions of tin for the Government stockpile surged and reached a peak of about 500,000 metric tons. In 1959, Congress approved tin sales from the Government stockpile. Tin was the first material to be sold from the stockpile (1960) and was offered for sale almost continuously up to the end of the century when sales had reduced tin stockpile inventories to 60,000 tons. Since establishment of the Government stockpile in 1939, tin has almost always had the highest inventory value in the stockpile.

In 2000, the United States had no domestic tin mine or smelter production. The country was dependent mostly on imports for its tin needs. Peru was the major supplier, followed by China, Bolivia, Brazil, and Indonesia. The United States remained the world's largest user of tin. Solder was the dominant market for tin consumption domestically, followed by tinplate, chemicals, and brass/bronze. The use of tin for tinplate had declined sharply since 1960 due to competition in the beverage container sector from materials like aluminum and plastics. Tin chemicals represented a somewhat new market essentially starting in the early 1950s

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tin was produced from various scrapped alloys of tin and recycled in those same alloy industries. In 2000, however, tin metal recovered from new tinplate scrap and used tin cans was the only type of secondary tin available in the marketplace as free tin. Secondary tin from recycled fabricated parts was used in many kinds of products and was particularly important for the manufacture of solder and brass/bronze.

The former Steel Can Recycling Institute, created in 1988 and funded by five domestic tinplate producers to advance the collection, preparation, and transportation of steel can scrap, was in its sixth full year of expanded activities in 2000 under its new name, The Steel Recycling Institute (SRI). The SRI fostered the collection of all steel scrap (ranging from appliances to cars), not just steel cans. Its representatives in various regions of the United States continued to work with municipalities, scrap dealers, and detinners to promote the recycling of tin cans. The SRI announced that the recycling rate for steel cans, most of which are made from tinplate, remained at about the same rate (58%) as in 1999 (Steel Recycling Institute, 2001).

APEAL, a Belgium-based organization of European packaging firms that use considerable amounts of tinplate, released 1999 data on the recycling of steel packaging in Europe. The data indicated a marked increase in recycling rates for most countries in the European Union (EU). The overall rate for recycling was 46%. Germany ranked first with an 80% recycling rate, mostly due to its selective, multimaterial collection system. Integral collection and magnetic separation prior to incineration still account for over one-half of recycled steel packaging in the EU, but the more recent introduction of curbside collections and recycling banks has been so successful that APEAL considers the combined approach as essential (Metal Bulletin Monthly, 2000b).

Consumption

In 2000, domestic consumption of primary tin remained almost identical to that of 1999. Secondary consumption increased slightly. Domestic consumption data for tin were developed by the USGS from a voluntary survey of tin consumers. Of the 149 firms to which a survey form was sent, 125 responded, for an 84% response rate (table 3).

In 2000, tinplated steel and tin-free cans accounted for 23% of the 136 billion metal cans shipped domestically; aluminum cans accounted for the remainder. The proportions were the same as in 1999. Steel tinplate dominated in the food, pet, and the "general line" can markets, and aluminum held 100% of the beverage can market (Can Manufacturer's Institute, 2001).

The U.S. Steel Group of USX Corp. (Pittsburgh, PA) announced late in the year that it would acquire the tin mill products business of LTV Corp. (Cleveland, OH); the acquisition was completed early in 2001. The tin mill products operations that were acquired are in Aliquippa, PA, and East Chicago, IN. Upon takeover, U.S. Steel shutdown the Aliquippa facility. Under the terms of agreement with LTV, U.S. Steel assumed about $95 million of LTV's employee related obligations, including shutdown benefits for about 400 workers at the tin mill in Aliquippa, PA, and the assumption of pension, medical, and life insurance obligations for all employees. About one-half of the expense was covered by U.S. Steel's overfunded pension plan. The LTV purchase made U.S. Steel Corp. the Nation's major producer of tin mill products. In acquiring LTV's 500-employee tin mill at its large Indiana Harbor Works in East Chicago, IN, U.S. Steel boosted its capacity to produce tin-coated sheet to about 1.7 million metric tons per year (Mt/yr). U.S. Steel tin mills at its large Gary, IN, works and at its smaller Fairless Works (Fairless Hills, PA) together can produce about 1.3 Mt/yr. The domestic tinplate market is estimated to be about 4.5 Mt/yr (American Metal Market, 2000).

Weirton Steel Corp. (Weirton, WV) announced that it will enter the coated coil industry when it begins a new polymer film coating line during the first half of 2001. The planned line will have the capacity to apply a thin coat of polymer film on 200,000 t/yr of tinplated steel. Several sites for the facility are being considered. The polymer coating process is a new technology that reportedly is superior to conventional lacquer coating systems. Polymer-coated tinplate is used for the top and bottom lids of food containers, aerosol cans, and other containers. Weirton has been the largest U.S. tinplate producer for many years and is the eighth largest domestic integrated steel company (Weirton Steel Corp., 2000).

Prices

The Platt's Metals Week average composite price for tin metal rose by 1% during 2000 compared with that of 1999. The Platt's Metals Week average commodity price was $3.98 per pound in January, its highest monthly level all year. And, it ended the year at $3.59 per pound, in December, its lowest monthly level all year.

The London Metal Exchange (LME) remained the primary trading arena for tin. Tin was one of only six metals to be traded on the LME; the other metals included aluminum, copper, lead, nickel, and zinc. The LME announced the start of trading on its new LMEX contract on April 10. LMEX is a futures-based weighted index contract covering the six primary nonferrous metals traded on the LME. The new index uses a base of 1,000 points calculated from January 4, 1999. At the end of the first day's trading, the index stood at 1,270 points. LMEX is designed to attract the institutional investor by spreading liquidity across all the metals and thus reducing volatility in each metal contract. Initially, LMEX had 15 of the 40 LME member firms involved in the new contract. Other firms are expected to follow (Tin International, 2000b).

The LME announced that it was considering the storage of tin in Singapore. In the past, Singapore had been ruled out for such tin storage because it is near sizable production facilities, and the LME's policy has been to site delivery points in areas of net consumption (Platt's Metals Week, 2000c).

The Kuala Lumpur Tin Market (KLTM) announced that it had received the needed approvals for trading its tin contracts in United States dollars. Its board subsequently decided to change contract pricing from the Malaysian ringgit to the dollar starting on February 2, 2001. The KLTM was established in 1984 as a physical market to provide facilities for buying and selling tin and for the daily determination of tin prices. Its contract calls for trading tin on warrants for prompt delivery, within four business days, of the following brands: MSC (Malaysia), Thaisarco (Thailand), and Bangka and Mentok (both Indonesia).

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The KLTM daily price quotation has been traditionally used as a reference price for contract pricing for producers and consumers in the Asia-Pacific region, which produces over 80% of the world's tin. Along with the change to a dollar contract, the KLTM board also decided to introduce electronic daily trading to replace the current pit system of daily price setting. This new system is to be implemented by June 2001 (Tin International, 2000b).

Trade

U.S. imports of refined tin, which supplied most domestic tin requirements, decreased by 5% in 2000. Imports of tin in all forms (ore and concentrate, metal, waste, and scrap) remained duty free (tables 7 and 8). In the United States, trading firms marketed most of the tin metal imported from a variety of countries and then warehoused in this country until sold to customers. Foreign-owned trading firms tended to dominate the domestic field.

Imports of refined tin to the United States were dominated by China and Peru. Bolivia, Brazil, and Indonesia ranked next in importance. Tin exports were small compared with imports (table 6).

After the U.S. Department of Commerce assessed antidumping duties of over 95% against four Japanese tinplate producers, based on an investigation covering a period from October 1, 1998, through September 30, 1999, the U.S. International Trade Commission (ITC) imposed a 95% antidumping duty on most tinplate imports from Japan. The final affirmative injury determination drew a strong negative response from Japanese tin mill owners because the ITC found injury in a case that had only one domestic tin mill petitioner, Weirton Steel Corp., Weirton, WV. Weirton, the only one of seven major U.S. tinplate producers to file the antidumping petition, claimed that the ITC ruling was crucial for the company's long-term viability. Weirton has been the largest U.S. tinplate producer for many years, with a 22% market share. The ITC's 95% duty will apply to imports from Kawasaki Steel Corp., Nippon Steel Corp., NKK Corp., and Toyo Kohan Corp., the major Japanese tinplate exporters. The United States imported about 337,000 t of tinplate from Japan in 1999, up from an average of about 210,000 t/yr in the prior 3 years (Metal Bulletin, 2000h).

World Review

Argentina.—Sunshine Mining and Refining Co. (USA) announced that it is still attempting to find sources of funding to develop its Pirquitas silver-tin-zinc mine in Argentina. The company has had an operating permit since 1999 but has been frustrated by financing problems arising from the low price of silver. Sunshine, primarily a silver miner, originally bought the mine in 1995 for $1.7 million. The property had been mined for many years by local operators who went into liquidation in 1990. Sunshine has since invested $20 million in the project (Tin International, 2000b).

The country's only tinplate producer, Siderar SAIC, returned its only tinning line to production following modernization by Techint Technologies Co. (Pittsburgh, PA). The line's speed was increased from 244 meters per minute to 305 meters per minute. The line's capacity is now 150,000 t/yr compared with a previous 120,000 t/yr. Siderar's tinning line produces mainly for domestic markets (Metal Bulletin, 2000f).

Australia.—Murchison United NL announced an agreement with the Tasmanian State Government to jointly fund a $22 million, 6-year exploration and development program aimed at securing the long-term future of the company's Renison Bell tin mine. This new program will enhance a prior $13 million program already underway at Renison designed to convert existing inferred resources to reserves and extend mine life beyond 10 years. Murchison acquired Renison in 1998 and has since been transforming it into one of the world's lowest-cost tin mines.

Marlborough Resources NL Group announced that it had reached an agreement to acquire a subsidiary of Western Metals Ltd., which owns the defunct Ardlethan tin mine, for an agreed purchase price of $1. Marlborough will take responsibility for rehabilitation of the old tin project, which was closed down in 1986. Tailings dams at the site contain about 8 Mt of tailings with a grade of about 0.19% tin. Thus, about 15,000 t of tin are contained in the tailings, which have a current in-situ value of about $90 million. Marlborough has conducted several detailed studies of these tailings over the past 20 years and believes that recoveries of between 55% to 65% may be possible depending on the process used. The firm also will be conducting further test work on the site to determine the most economical process and equipment to maximize profitability from the treatment of tailings. The firm plans to transport the retreated tailings back into the original open cut. In addition to the tailings, there are significant alluvial tin resources on some of the 53 mineral tenements included with the acquisition (Tin International, 2000e).

Phelps Dodge Corp. (USA) announced that it agreed to join the Australian company, Platsearch Ltd., in its Tara copper-zinc-tin exploration project in New South Wales. Under the terms of the agreement, Phelps Dodge can earn a 60% stake in Tara by spending $1.2 million on a ground magnetic survey and a 400-meter drill hole. Once Phelps Dodge has earned its 60%, Platsearch and its existing partner, Nosebi Mining and Management, will participate at 32% and 8%, respectively. Previous drilling at Tara intersected narrow widths of copper-zinc-tin mineralization. Phelps Dodge planned to begin drilling in 2000 (Platt's Metals Week, 2000e).

Bolivia.—The ownership of the Vinto tin smelter and the Huanuni tin mine completely transferred to Allied Deals Corp. Allied paid $15 million for the smelter and associated assets and also paid $500,000 for a 30-year lease on what may be the world's largest underground tin mine. Vinto produces about 11,000 t/yr of low-lead tin. Allied plans to increase production at Vinto to 15,000 t/yr in 2001-2002 and then to further increase output to 18,000 to 20,000 t/yr in 2 more years. Also, new sources of tin concentrate would be sought; Vinto's feedstock now comes from Bolivia and Brazil (Platt's Metals Week, 2000g).

Brazil.—The country's largest steelmaker, Compañia Siderúrgica Nacional (CSN), announced that it was seeking contractors to modernize the company's no. 3 and no. 5 electrolytic tinning lines at its Volta Redonda Works. Work is expected to start in January 2001 on the $150 million modernization. The upgrade will allow CSN to produce thinner

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and more sophisticated grades of tinplate, including double-reduced grades as well as drawing and ironing grades for two-piece beverage cans. CSN has six tinning lines at Volta Redonda with a combined capacity of 1.1 Mt/yr of tinplate. CSN is the world's fifth largest tinplate producer and the largest on a single site. About 70% of CSN's tinplate output is used domestically and 30% is exported (Metal Bulletin, 2000b).

Chile.—The largest Chilean steel producer, Compañia Siderúrgica Huachipato (CSH), a subsidiary of Chile's Cap Group, celebrated its 50th anniversary. CSH is Chile's only integrated steelmaker. Located along the San Vicente Bay in southern Chile, the plant employs almost 3,000 workers and has the capacity to produce 1.2 Mt/yr of steel. Among its several finishing mills is a tin mill with a Ferrostan electrolytic tinning line that has an annual capacity of 100,000 t (Metal Bulletin Monthly, 2000a).

China.—The Government of China, the world's largest tin producer, announced that it will seek to attract foreign investment for mining in Xinjiang Province, in northwestern China. The Government intends to adopt preferential policies to attract foreign capital to tap vast resources of natural gas, coal, and nonferrous metals in Xinjiang along with state-owned mining enterprises. Foreign companies that invest in Xinjiang will be eligible for exemption from fees for mining rights in the first year and a subsequent 50% reduction for the next 2 years. Wholly owned foreign companies and joint ventures will be exempt from mineral resource compensation fees for 5 years. Also, the Government will seek to attract investment by issuing stocks, holding assets sales, and franchising. China believes these moves would accelerate its entry into the World Trade Organization and further lift its economy. Geologists working in Xinjiang recently discovered deposits of copper, nickel, lead, zinc, and tin near the province of Urumqi, an estimated total of about 1.2 Mt of base metal ores in an area covering almost 860,000 square kilometers (Metal Bulletin, 2000a).

The country's major tin producer, Yunnan Tin Corp., announced that it expected a delay in the completion of its new furnace, citing technical difficulties. Officials projected a late 2001 startup. Yunnan is upgrading its 24,000 t/yr tin smelter in Gejiu City by replacing several reverberatory furnaces with a new furnace. The furnace will continue to process 50,000 t/yr of concentrate and produce 24,000 t/yr of refined ingot. Yunnan has invested $12 million in the upgrade. In 2000, Yunnan continued to target a maximum output of 24,000 t of refined tin, which is in-line with 1999 production (Platt's Metals Week, 2000h).

Denmark.—The Government announced plans to impose a wide-ranging ban on the use of lead. It would be the first country to do so. The ban becomes effective March 1, 2001, and will affect the use of lead and lead compounds in the construction and electronics industry, use of lead as a stabilizer in plastics, and use of metallic lead in ballasts and weights. The ban has implications for tin because tin is often used as a replacement for lead in such applications (Mining Journal, 2000b).

Germany.—The Government was considering extending its deposit system for used beverage containers to include disposable steel (tinplate) and aluminum cans. According to the deposit proposal, a fee of 50 pfennigs (49 cents) would be imposed on each disposable can as well as on glass and plastics bottles. The deposit would be refunded when the container is returned. Glass or plastic bottles already carry a deposit of between 15 and 70 pfennigs each. All other beverage packaging currently is discarded, although much of it enters the recycling chain. In Germany, over 90% of cans are made from steel, amounting to roughly 170,000 t of tinplate. Recycling of tinplate is now at about 80% in Germany, the highest rate in Europe (American Metal Market, 2001).

The country's only tinplate producer, Rasselstein Hoesch GmbH (RHG), owned by ThyssenKrupp AS announced plans to shutter one of its plants in an attempt to bolster profitability. The plant to be closed is RHG's Dortmund facility, with a tinplate capacity of 180,000 t/yr. Its closure is set for three stages, with operations to cease completely by the end of 2001. RHG has its main plant in Andernach, with tinplate capacity of 900,000 t/yr. Its capacity is to be expanded to 1 Mt/yr by the end of 2001 (Tin International, 2000f).

Indonesia.—PT Timah, the country's largest tin producer, announced an anticipated decline of 12% in its refined tin output during 2000. The company attributed lower output to predicted poor weather and declining resources. Timah is still attempting to resolve long-standing land ownership issues with local inhabitants on the islands of Bangka and Belitung, the sites of most of its tin mining and smelting. Timah acknowledged that additional uncertainty looms as the Indonesian Government appears set to declare Bangka Island as a province, possibly giving local authorities autonomous powers. If that becomes a reality, the company may be forced to pay separate royalties to the local Bangka provincial administration. Timah is currently seeking opportunities to expand its tin operations into Burma, Cambodia, and Vietnam (Metal Bulletin, 2000d).

The Government announced that it has granted PT Koba Tin a 10-year extension of its contract to operate in Indonesia. Koba Tin is 75% owned by Iluka Resources NL (Australia). Koba has been mining tin at a rate of 10,000 t/yr (Platt's Metals Week, 2000b).

Herald Resources Ltd. (Australia) announced the discovery of significant tin mineralization during a drilling program at is Batu Besi property on Belitung Island. Tin values in the range of 1.2% have been reported. The island has long been home to major tin mining operations of PT Tambang Timah (Mining Journal, 2001a).

Japan.—The country's tinplate industry finds itself in an acutely competitive market. Over the past 4 years, consumption of beverages in tinplate cans has fallen as part of an overall decrease in the consumption of canned beverages in Japan. The tinplate makers are facing greater competition from popular, portable half-liter plastic bottles that have garnered a growing share of the packaging market for carbonated and noncarbonated beverages. In 1999, about 35 billion cans made of tinplate, tin-free steel (TFS), and aluminum were used in Japan. This total represent an 8% decline in can consumption compared with about 38 billion cans used in1998, and a 13% decline compared to the 40 billion cans used in 1996. Steel cans are estimated to account for about 60% of all cans used in Japan; of these, tinplate and low-tin cans represent 35%, while TFS cans account for the remaining 25% share; aluminum cans represent the other 40% share of the can market.

In 1999, Kawasaki Steel Corp. produced 25,000 metric tons

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per month (t/mo) of tinplate a month for local sale and export; about 11,000 t/mo of TFS was produced for local and overseas sale. Kawasaki's output included a low-tin coated steel designed for making three-piece cans. In the production process, an iron-nickel-tin alloy layer is formed by electrotinplating and a flow melting process. The low-tin product accounts for 25% of the firm's tinplate output. Most of the product is supplied to Japanese canmakers to make beverage cans for coffee and sports drinks.

In 1999, Kawasaki exported a total of 170,000 t of tinplate. One-half of the firm's tinplate exports are shipped to the United States, while other big markets are China, Indonesia, and the Philippines. Until recently, Japanese steel mills supplied about 350,000 t/yr of tinplate to the United States, accounting for almost 10% of the U.S. tinplate market. In 1999, Kawasaki supplied 88,000 t of tinplate to U.S. customers, representing 25% of total Japanese tinplate exports to the United States (Tin International, 2000a).

Korea, Republic of.—This country, with four tinplate producers, has become a major force in the tinplate market during the past decade. The Republic of Korea's tinplate consumption is estimated at 385,000 t/yr, and imports account for about 25,000 t of that total. Pohang Iron and Steel Corp. (POSCO) was the country's leading domestic tinplate market supplier with an estimated 31% market share in 1999, representing tinplate sales of 110,000 t/yr. The second largest local supplier was Dongbu Steel Corp. with sales of 96,000 t in 1999, or about a 27% market share. In third place was Dongyang Corp. with an estimated 26% domestic market share, or 92,000 t of sales. Shinwha Corp. was in fourth place with sales of 57,000 t and a 16% local market share. Both Dongbu and Dongyang have a larger tinplate manufacturing capacity than POSCO but rely on exports for about one-half their sales. Export orders are important to all four tinplate makers. In 1999, Dongbu and Dongyang were expected to ship export orders far exceeding their domestic sales, while POSCO and Shinwha were expected to supply about one-half of their output to domestic customers. The Republic of Korea's total tinplate-making capacity is about 850,000 t/yr, almost one-half of which is used for export purposes.

Dongbu overtook Dongyang as the Republic of Korea's largest tinplate producer with the startup of its Asan Bay electrolytic tinning line that has a top speed of 650 meters per minute. Dongbu is now able to produce 280,000 t/yr of tinplate; Shinwa produces 90,000 t/yr. The other producer, POSCO, ranks as one of the world's major steel companies and has an annual production of 770,000 t of blackplate substrate. In addition to supplying the domestic market, POSCO exports about 75,000 t/yr. POSCO's main tinplate markets are India and Southeast Asia (Tin International, 2000e).

Malaysia.—The long, narrow, and highly productive Southeast Asian Tin Belt extends over the entire length of the Malay peninsula. It includes parts of Burma and Thailand to the north as well as Malaysia and some western Indonesian islands to the south. The Malaysian portion of the Tin Belt contains about 40% "acid intrusives," presumably granite, mostly in three very long, irregular intrusive zones. These zones generally parallel the north-south trend of the peninsula. The largest of the three, in west-central Malaysia, extends into Thailand. It resembles the Sierra Nevada, CA, and the adjacent Coast Range, British Columbia, Canada, intrusive belts in Western North America. Host rock for the Malaysian intrusive is mostly Paleozoic sedimentary rock with minor volcanics. Malaysian bedrock tin deposits are presumed to be closely associated with a small Permian-to-Triassic-age granite center within the three much larger regional granite masses.

Most of Malaysia's tin mines are in the States of Perak and Selangor. In an attempt to revitalize the tin industry, officials in Perak issued mining licences during 2000. However, Government assistance to find and develop tin prospects reportedly has been lacking in recent years. In 1989, the Government requested the United Nations (UN) to study the situation and make recommendations. In 1991, a UN report was submitted, and the Malaysian Federal Parliament took legislative and regulatory actions in response. Because Malaysian States have autonomy over mining matters, however, the Federal initiatives must await acceptance by the States. Selangor and Sebah States have already accepted the initiatives. The belief is that sufficient resources are available. Presumably, all that is needed to return Malaysia to prominence in tin mining is increased Government support for investment, exploration, and development in the mining sector (Engineering and Mining Journal, 2000).

The Chamber of Mines announced that there were 45 active tin mines in the country in October 1999, 15% more than the 39 mines active in January 1999. Despite this, tin mine output has remained about the same (Platt's Metals Week, 2000d).

Nigeria.—Malaysia Mining Corp. (MMC) was reportedly close to signing an agreement with the Nigerian Mining Corp. (NMC). NMC is a Government-owned entity that holds the leases to most mining rights in the country and manages controlling shares in Consolidated Tin Mines Ltd. NMC officials acknowledged that Nigeria's tin properties require fresh investment and new technologies. MMC has been seeking new opportunities to invest in tin and other metal operations outside Malaysia and further utilize its lengthy mining experience (Metal Bulletin, 2001).

Peru.—The country's major tin miner, Minsur, announced plans to invest $7 million this year in exploration work. During 1999, Minsur completed an expansion at its mine, increasing the production rate from 1,500 metric tons per day (t/d) of tin ore to 2,500 t/d. As a result, the company expects to produce about 3,500 t/yr of tin-in-concentrate. Minsur's Funsur tin smelter production is expected to reach 22,000 t of tin metal in 2000, compared with 18,000 t in 1999.

Russia.—The country's only tin smelter, the Novosibirsk Tin Combine, announced plans to increase output by more than 50% over that of 1999. The firm expected to produce 6,000 t of refined tin and 3,000 t of solder. It also plans to raise total annual output to 20,000 t in 2001, a level not achieved since 1986, to meet increased domestic demand. Novosibirsk plans to move ahead with the development of its resource base in 2001 by making acquisitions and increasing production of tin concentrate at the four mining complexes that it controls or partially owns. By yearend 2000, the four complexes in which Novosibirsk owns an interest were expected to achieve a production level that will cover at least 80% of the smelter's needs, with the Deputakskolovo Tin Mine providing one-half of the total. The firm started a long-term investment program at Deputakskolovo with a total cost of about $5 million. The aim

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is to increase mine output there by 30% to 40%. The mine is in far eastern Russia at Yakutia and is ice-bound for much of the year (Tin International, 2000d).

Slovakia.—Shareholders in the Slovak steel group, VSZ a.s, approved a plan which would allow U.S. Steel Group to acquire the company's core assets, including its tinplate operations. The deal would add about 3.4 Mt of crude steel production to U.S. Steel's existing 11 Mt. About 84% of VSZ's stockholders gave their support to the proposal as stated in a memorandum of understanding. Officials indicated that U.S. Steel had committed $700 million in capital spending for the first phase of a VSZ modernization program. Initially, the company will complete the upgrade of its current 50-50 tinplate joint venture with VSZ by installing a 200,000-t/yr continuous annealing line. A $26 million temper line will also be installed, followed by a new 200,000-t/yr tinning line. Upon completion of the acquisition, U.S. Steel would target sales primarily within Central and Eastern European markets. U.S. Steel officials believe that markets within 600 kilometers (km) of the Kosice plant location are sufficient to absorb expected mill capacity (Metal Bulletin, 2000g).

Thailand.—The Department of Mineral Resources reported that Thai tin-in-concentrate production increased 69% to 2,700 t in 1999 compared with 1,600 t in 1998. Officials attributed the rise mostly to the increased number of active mines in 1999 (30 compared with 23 mines in 1998). Thailand has only one tin smelter, Thaisarco, which has a maximum output capacity of 36,000 t/yr of refined tin metal. Thaisarco produced 17,000 t of tin metal in 1999, an 11% increase over the 15,000 t produced in 1998. Thailand's tin metal exports were 13,000 t in 1999, compared with 11,000 t in 1998. Domestic tin sales increased 20% in 1999 to 4,800 t (Platt's Metals Week, 2000f).

Turkey.—The country's only tinplate producer, Erdemir, announced that it had increased tinplate output at its Eregli Works from 100,000 to 300,000 t/yr. The increase followed the recent addition of a new tinning line, an electrolytic cleaning line, and a shearing line (Metal Bulletin, 2000c).

United Kingdom.—A proposal was made to reopen the South Crofty Tin Mine by Baseresult plc, a local Cornwall firm. South Crofty was England's last operating tin mine when it closed in 1998. Baseresult was negotiating with South Crofty plc (the mine's owner) for the mine, land comprising the mine-site, and processing equipment from the Wheal Jane concentrator plant nearby. South Crofty's mining permit was extended to allow the negotiations to continue. Baseresult plans to produce 2,000 t/yr of tin-in-concentrate at an operating cost of $2,800 per metric ton of tin, well below the current cost $5,510 per metric ton. However, officials believe the mine can be profitable only if the company diversifies the operation to include other activities (such as waste management from energy facilities in the region). Nevertheless, officials expressed confidence that Baseresult can extend the life of the mine beyond the 7 years during which its plans to mine the upper levels of the deposit (Platt's Metals Week, 2000a).

In Yorkshire, Rio Tinto Ltd. announced that it expected to disprove in court allegations that its former Capper Pass Tin Smelter caused injuries or illnesses among workers and local residents. Rio Tinto's subsidiary, Capper Pass and Son Ltd., located in Hull, was the world's largest tin smelter at the time of its closure in 1991. Rio has repeatedly rejected allegations that emissions from the smelter were responsible for medical problems among local residents and former employees, or that the emissions damaged the surrounding environment. No date has yet been set for a court hearing in the case (Metal Bulletin, 2000e).

Vietnam.—Tiberon Minerals Ltd. (Canada) announced that it had begun exploration work at a diverse metals deposit in the northern part of Vietnam. Along with tin, other discoveries at the Nui Phao site, about 80 km north of Hanoi, include bismuth, gold, and tungsten (CRU Tin Monitor, 2001).

Current Research and Technology

Crown, Cork and Seal Corp. (Philadelphia, PA), the world's largest packaging manufacturer, announced the development of a new beverage can end that offers reduced metal usage and easier opening. Crown believes the new style can end will afford substantial savings in material costs and can be applied equally to tinplate or aluminum ends. Currently, almost all beverage can ends in the United States are aluminum, but tinplate shares the remaining worldwide market (Canning and Filling, 2000).

Researchers at Leeds University in the United Kingdom announced the development of a new method of recycling steel, including steel tinplate, that reportedly is cheaper, requires no presorting of scrap, and may even produce a stronger material. All steel producers recycle a significant proportion of steel scrap. Tin from tinplate scrap and copper from domestic incinerator scrap accumulates in the steel, posing a major quality problem for the steel industry unless properly controlled. Such impurities in anything other than small amounts can have harmful effects on ductility, causing defects in the worked material. Unless removed or controlled by careful scrap selection, these impurities could rise to unacceptable levels over the next few years due to increased recycling targets. The Leeds team discovered that the controlled addition of aluminum to the molten steel during recycling forms alloys with the tin and/or copper rendering both harmless. The new steel alloy may even be improved by this patented process. Initial studies show that the presence of aluminum causes an increase in the hardness of the steel, implying an increase in mechanical strength. The source of aluminum can be pure metal, an alloy, or a compound capable of dissociation at the operating temperature. To the researchers, an obvious source would be aluminum cans, currently recycled separately from steel cans; they reason that the recycling industry ultimately could change and not separate steel and aluminum used cans, but instead charge mixed loads of scrap, thereby saving on sorting costs. The addition of a metal as an alloying agent is a radical departure from conventional treatments such as those used in detinning plants or plants to extract unwanted metals by chemical or electrochemical methods (Tin International, 2000f).

During Metal Bulletin's 6th International Tin Conference held in San Diego, CA, May 7-9, a researcher speaking for the International Tin Research Institute (ITRI) (Uxbridge, UK) focused on the potential market for tin usage in flame retardants. The speaker noted that among the current types of flame retardants, tin's best opportunity for market penetration are in fields currently served by antimony trioxide. In the late 1980s ITRI developed a zinc stannate compound as a fire

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retardant. This compound shows excellent smoke suppressant characteristics compared with antimony trioxide, but it is much more costly. ITRI continues its work in this area. The speaker indicated that the potential world replacement market for antimony trioxide is 36,000 t, of which 5,000 t may be a realistic target for tin over the next 10 years.

Outlook

Domestic demand for primary tin is expected to grow slowly in the next few years, at a rate of perhaps 1% per year. That rate could double in a few years, however, if new applications—especially those in which tin is substituted for toxic materials—find acceptance in the marketplace.

World tin reserves appear to be adequate to meet foreseeable demand. Secondary sources of tin are likely to remain an important component of tin supply, especially in the United States. The NDS sales are expected to continue in coming years and remain an important segment of domestic supply until the inventory is exhausted. Domestic tin needs, however, will probably continue to be met primarily through imports.

References Cited

American Metal Market, 2000, U.S. Steel Group set to acquire LTV tin unit: American Metal Market, v. 108, no. 195, October 9, p. 1.

———2001, Germany may extend container deposits: American Metal Market, v. 109, no. 4, January 5, p. 10.

Can Manufacturer's Institute, 2001, Metal can shipments by material, *in* Can Shipments Report, 2000: Can Manufacturer's Institute, 8 p.

Canning and Filling, 2000, End of the Era?: Canning and Filling, September, p. 28-29.

CRU Tin Monitor, 2001, Canadian Tiberon begins exploration: CRU International Ltd., February, p. 8.

Engineering and Mining Journal, 2000, Malaysian tin: Engineering and Mining Journal, v. 201, no. 12, December, p. 32-37.

Metal Bulletin, 2000a, China to foster mining investment in Xinjiang: Metal Bulletin, no. 8520, October 26, p. 5.

———2000b, CSN upgrades two tinning lines: Metal Bulletin, no. 8528, November 23, p. 17.

———2000c, Erdemir ramps up tinplate output: Metal Bulletin, no. 8534, December 14, p. 20.

———2000d, PT Timah predicts output will decline in 2001: Metal Bulletin, no. 8526, November 16, p. 9.

———2000e, Rio Tinto offer accepted in Capper Pass dispute: Metal Bulletin, no. 8482, June 8, p. 4.

———2000f, Siderar revamps tinplate line: Metal Bulletin, no. 8498, August 7, p. 20.

———2000g, VSZ shareholders vote to bring in US Steel: Metal Bulletin, no. 8479, May 29, p. 7.

———2000h, Weirton wins final ruling against Japanese tinplate: Metal Bulletin, no. 8498, August 7, p. 20.

———2001, Malaysian Mining Corp. moves into Nigerian tin: Metal Bulletin, no. 8543, January 22, p. 9.

Metal Bulletin Monthly, 2000a, Huachipato ready for better times: Metal Bulletin Monthly, no. 358, October, p. 25.

———2000b, More steel packaging recycled: Metal Bulletin Monthly, no. 360, December, p. 80.

Mining Journal, 2000a, Belitung tin discover: Mining Journal, v. 336, no. 8615, January 5, p. 7.

———2000b, Denmark to outlaw lead: Mining Journal, v. 335, no. 8611, December 1, p. 438.

Platt's Metals Week, 2000a, Baseresult targets 2,000 mt/yr tin at South Crofty: Platt's Metals Week, v. 71, no. 39, September 25, p. 12.

———2000b, Indonesia extends Koba's contract: Platt's Metals Week, v. 71, no. 37, September 11, p. 11.

———2000c, LME to consider warehousing tin in Singapore: Platt's Metals Week, v. 71, no. 21, May 22, p. 15.

———2000d, Malaysian tin mine numbers see-saw, output on target: Platt's Metals Week, v. 71, no. 18, May 1, p. 11.

———2000e, PD farms into Australian exploration: Platt's Metals Week, v. 71, no. 24, June 12, p. 15.

———2000f, Thailand's tin output jumps as more mines operate: Platt's Metals Week, v. 71, no. 8, February 21, p. 15.

———2000g, Vinto sale closing delayed-Allied mulls contracts: Platt's Metals Week, v. 71, no. 10, March 6, p. 4.

———2000h, Yunnan smelter delay: Platt's Metals Week, v. 71, no. 10, March 6, p. 5.

Steel Recycling Institute, 2001, Steel recycling rates: Pittsburgh, PA, Steel Recycling Institute news release, April 9, 1 p.

TIN International, 2000a, Kawasaki Steel Japan - tinplate market profile: TIN International, v. 73, no. 4, April, p. 15-17.

———2000b, KLTM moves to dollar contract and electronic trading: Tin International, v. 73, no. 10, October, p. 4.

———2000c, Marlborough on track to produce tin in 2001: TIN International, v. 73, no. 3, March, p. 3.

———2000d, NOK to boost output in 2000: TIN International, v. 73, no. 3, March, p. 3.

———2000e, POSCO—South Korea tinplate market revives in 1999: TIN International, v. 73, no. 1, January, p. 6-8.

———2000f, Rasselstein shutters plant: TIN International, v. 73, no. 1, January, p. 9.

Weirton Steel Corp., 2000, Weirton Steel to enter coated coil industry with opening of new polymer film coating line: Weirton, WV, Weirton Steel Corp. news release, June 26, 1 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Recycling—Metals. Ch. in Minerals Yearbook, annual.
Tin. Ch. in Mineral Commodity Summaries, annual.
Tin. Ch. in Minerals Yearbook, annual.
Tin. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Tin. International Strategic Minerals Inventory Summary Report, Circular 930-J, 1990.
Tin. Mineral Industry Surveys, monthly.
Tin Resources of the World, Bulletin 1301, 1969.

Other

Bottle/Can Recycling Update.
Canadian Mining Journal.
Resources Recycling.
Roskill Information Services Ltd.
Tin. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Wall Street Journal.

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TABLE 1
SALIENT TIN STATISTICS 1/

(Metric tons of contained tin, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production, secondary e/	11,600	12,400	16,300	16,400 r/	15,100
Exports, refined tin	3,670	4,660	5,020	6,770	6,640
Imports for consumption, refined tin	30,200	40,600	44,000	47,500	44,900
Consumption:					
Primary	36,500	36,200	37,100	38,000 r/	38,100
Secondary	8,180	8,250	8,620	8,890	8,940
Stocks, yearend, U.S. industry	10,900	11,200	10,500	10,700	10,400
Prices, average:					
New York market cents per pound	288.10	264.45	261.38	254.54	254.92
Platt's Metals Week composite do.	412.43	381.49	373.26	365.98	370.16
London do.	279.00	256.00	251.00	245.00	246.00
Kuala Lumpur do.	275.19	252.24	246.06	240.70	244.12
World, production:					
Mine	220,000	217,000	207,000 r/	216,000 r/	238,000
Smelter:					
Primary	211,000	222,000 r/	226,000	236,000 r/	258,000 e/
Secondary	16,700	17,500	20,400	25,900	27,600 e/
Undifferentiated	200	200	200	100	--

e/ Estimated. r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits.

TABLE 2
U.S. CONSUMPTION OF PRIMARY AND SECONDARY TIN 1/

(Metric tons of contained tin)

	1999	2000
Stocks, January 1, 2000 2/	9,290	8,910
Net receipts during year:		
Primary	40,500 r/	41,400
Secondary	2,790	2,990
Scrap	6,360 r/	6,080
Total receipts	49,700 r/	50,400
Total available	58,900 r/	59,300
Tin consumed in manufactured products:		
Primary	38,000 r/	38,100
Secondary	8,890	8,940
Total	46,900	47,000
Intercompany transactions in scrap	82 r/	85
Total processed	47,000 r/	47,100
Stocks, December 31, 2000 (total available less total processed)	11,900	12,300

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes tin in transit in the United States.

TABLE 3
U.S. CONSUMPTION OF TIN, BY FINISHED PRODUCT 1/

(Metric tons of contained tin)

	1999			2000		
Product	Primary	Secondary	Total	Primary	Secondary	Total
Alloys (miscellaneous) 2/	W	W	W	W	W	W
Babbitt	1,450	156	1,610	1,510	152	1,660
Bar tin	721 r/	W	721 r/	714	W	714
Bronze and brass	1,450	1,960	3,410	1,450	1,900	3,360
Chemicals	8,220	W	8,220	8,040	W	8,040
Collapsible tubes and foil	23 r/	W	23 r/	W	W	W
Solder	12800	5,960	18,700	12700	6,130	18,800
Tinning	905 r/	W	905 r/	1,200	W	1,200

See footnotes at end of table.

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TABLE 3--Continued
U.S. CONSUMPTION OF TIN, BY FINISHED PRODUCT 1/

(Metric tons of contained tin)

Product	1999			2000		
	Primary	Secondary	Total	Primary	Secondary	Total
Tinplate 3/	9,150	--	9,150	8,800	--	8,800
Tin powder	W	W	W	W	W	W
Type metal	W	W	W	W	W	W
White metal 4/	943 r/	W	943 r/	1,260	W	1,260
Other	2,390 r/	822	3,220 r/	2,390	754	3,140
Total	38,000 r/	8,890	46,900 r/	38,100	8,940	47,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes terne metal.
3/ Includes secondary pig tin and tin acquired in chemicals.
4/ Includes pewter, britannia metal, and jewelers' metal.

TABLE 4
U.S. INDUSTRY YEAREND TIN STOCKS 1/

(Metric tons)

	1999	2000
Plant raw materials:		
Pig tin:		
Virgin 2/	7,030 r/	6,940
Secondary	882	834
In process 3/	1,080 r/	1,060
Total	8,990 r/	8,830
Additional pig tin:		
Jobbers-importers	1,470	1,240
Afloat to United States	240	340
Total	1,710	1,580
Grand total	10,700	10,400

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes tin in transit in the United States.
3/ Data represent scrap only, tin content.

TABLE 5
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF NEW AND OLD SCRAP AND TIN RECOVERED, BY TYPE OF SCRAP 1/

(Metric tons)

Type of scrap	Gross weight of scrap						Tin recovered e/ 2/		
	Stocks, January 1	Receipts	Consumption New	Consumption Old	Consumption Total	Stocks, December 31	New	Old	Total
1999:									
Copper-base scrap	6,350	124,000	28,000	96,000	124,000	6,450 r/	1,230	3,620	4,860
Brass mills 3/	--	57,600	57,600	--	57,600	--	947	--	947
Foundries and other plants	2,270 r/	17,800 r/	5,970	12,000 r/	18,000 r/	2,110 r/	282	426 r/	708 r/
Total	XX	XX	XX	XX	XX	XX	2,460	4,050 r/	6,510 r/
Lead-base scrap	25,400	1,310,000	61,200	1,250,000	1,310,000	22,000 r/	1,610	3,670	5,280
Tin-base scrap 4/	W	W	W	W	W	W	4580	W	4,580
Grand total r/	XX	XX	XX	XX	XX	XX	8 650	7 720 r/	16,400 r/
2000:									
Copper-base scrap	6,450	141,000	57,700	82,600	140,000	6,170	1,160	3,120	4,270
Brass mills 3/	--	123,000	123,000	--	123,000	--	1,650	--	1,650
Foundries and other plants	2,110	17,400	W	W	17,800	1,690	W	425	425
Total	XX	XX	XX	XX	XX	XX	2,800	3,540	6,340
Lead-base scrap	22,000	1,010,000	50,700	958,000	1,010,000	19,400	1,330	3,060	4,390
Tin-base scrap 4/	W	W	W	W	W	W	4320	W	4,320
Grand total	XX	XX	XX	XX	XX	XX	8,450	6,600	15,100

See footnotes at end of table.

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TABLE 5--Continued
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF NEW AND OLD SCRAP AND TIN RECOVERED, BY TYPE OF SCRAP 1/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Tin recovered from new and old copper-base scrap, brass mills, and foundries.
3/ Brass-mill stocks include home scrap, and purchased-scrap consumption is assumed to be equal to receipts; the line, therefore, does not balance.
4/ Includes tinplate and other scrap recovered at detinning plants.

TABLE 6
U.S. EXPORTS OF TIN IN VARIOUS FORMS 1/

	Tinplate and terneplate		Ingots and pigs		Tin scrap and other tin-bearing material except tinplate scrap 2/	
Year	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
1999	290,000	$172,000	6,770	$38,100	33,200	$56,100
2000	300,000	163,000	6,640	35,300	26,200	48,800

1/ Data are rounded to no more than three significant digits.
2/ Includes rods, profiles, wire, powders, flakes, tubes, and pipes.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF TIN IN VARIOUS FORMS 1/

		Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.		Tinplate and terneplate		Tin compounds		Tinplate scrap	
Year	Miscellaneous 2/ value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
1999	$4,830	3,870	$7,840	449,000	$255,000	411	$3,550	58,000	$5,270
2000	5,680	5,170	17,700	359,000	206,000	586	4,740	14,500	1,660

1/ Data are rounded to no more than three significant digits.
2/ Includes tinfoil, tin powder, flitters, metallics, manufactures, n.s.p.f.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT TIN METAL, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	258	$1,250	317	$1,600
Belgium	182	1,110	74	502
Bolivia	3,850	20,800	6,330	35,600
Brazil	4,700	25,800	5,860	31,500
Canada	72	451	10	64
Chile	3,980	21,100	2,630	14,700
China	13,900	71,800	10,200	55,900
Hong Kong	261	3,360	397	2,330
Indonesia	7,930	42,200	5,320	29,100
Malaysia	944	5,200	214	1,180
Netherlands	19	2,110	--	--
Peru	11,000	58,100	12,800	69,200
Singapore	60	306	20	114
Thailand	20	101	--	--
United Kingdom	60	352	514	1,310
Other	284	1,440	178	968
Total	47,500	255,000	44,900	244,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 9
TIN: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Australia	8,828	10,169	10,204	10,038	9,146 3/
Bolivia	14,802	12,898	11,308	12,417 r/	12,464 3/
Brazil	19,617	19,065	14,607	13,200	13,000
Burma 4/	459	335	221	149	220
Burundi e/	25 3/	(5/)	23	10	10
Cameroon e/	1	1	1	1	1
China e/	69,600	67,500	70,100	80,100 r/	97,000
Congo (Kinshasa)	--	--	--	50 e/	50
Indonesia	52,304	55,175	53,959	47,754	48,000
Laos	1,056 r/	717 r/	627 r/	492 r/	600
Malaysia	5,174 r/	5,065	5,754 r/	7,340	6,307 3/
Mexico	2	5	5	4 r/	5
Mongolia	18	10	40	--	--
Niger e/	10	10	10	20	20
Nigeria e/ 6/	139 3/	150	200	200	300
Peru	27,004	27,952	25,747	30,403	37,410 p/
Portugal	4,637	2,667	3,100 r/	2,200 r/	1,200
Russia e/	8,000	7,500	4,500	4,500	5,000
Rwanda	260 r/	258 r/	260 r/	243 r/	344 3/
Spain e/	2	2	2	2	3
Thailand	1,300 r/	746 r/	1,656 r/	2,712 r/	1,930 3/
Uganda	(5/)	2 r/	1 r/	-- r/	-- 3/
United Kingdom	2,103	2,396	376	--	--
Vietnam e/	4,500	4,800 r/	4,500	4,500 r/	4,500
Zimbabwe e/	10 3/	10	1	1	1
Total	220,000	217,000	207,000 r/	216,000 r/	238,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 4, 2001.

3/ Reported figure.

4/ Includes content of tin tungsten concentrate.

5/ Less than 1/2 unit.

6/ Concentrate gross weight reported, estimated 62% Sn content.

TABLE 10
TIN: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Argentina, primary e/	-- r/	-- r/	-- r/	-- r/	--
Australia:					
Primary	460	605	655	585	775 3/
Secondary e/	300	300	300	300	300
Total e/	760	905	955	885	1,080
Belgium, secondary e/	3,000	3,000	2,500	8,100 r/	8,500
Bolivia, primary	16,733	16,853	11,102	11,166 r/	9,353 3/
Brazil:					
Primary	18,361	17,525	17,500 e/	13,200	13,000 3/
Secondary e/	250	250	250	250	250
Total e/	18,600	17,800	17,800	13,500	13,300
Bulgaria, secondary	8	10	10 e/	10 e/	10
Burma, primary	310 r/	228 r/	31 r/	32 r/	30
China, primary e/	71,500	67,700	79,300	90,800 r/	111,000
Czech Republic, secondary e/	100	100	100	100	100
Denmark, secondary e/	100	100	100	100	100
Germany, primary and secondary e/	100	100	100	--	--
Greece, secondary e/	100	150	200	200	150
Indonesia, primary	39,000 e/	52,658	53,401	49,105	50,000
Japan, primary	524	507	500	568 r/	593 3/
Malaysia, primary	38,051	34,822 r/	27,201 r/	28,913 r/	27,200
Mexico, primary	1,234	1,188	1,078 r/	1,258 r/	1,300

See footnotes at end of table.

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TABLE 10--Continued
TIN: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Nigeria, primary	100	100 e/	150	50 e/	100
Norway, secondary e/	50	50	50	50	50
Peru, primary	2,370	8,999	14,363	16,960	20,000
Portugal, primary and secondary e/	100	100	100	100	--
Russia: e/					
Primary	9,000	6,700	3,000	3,400 r/	4,700
Secondary	1,000	1,000	500	400 r/	500
Total	10,000	7,700	3,500	3,800 r/	5,200
Spain: e/					
Primary	150	150	100	50	--
Secondary	50	50	50	50	25
Total	200	200	150	100	25
Thailand, primary	10,981	11,986	15,353	17,306	17,076 3/
United Kingdom, secondary e/	100	100	50	--	--
United States, secondary	11,600	12,400	16,300	16,400 r/	15,100
Vietnam, primary	2,300	2,400	2,400 e/	2,400	2,400 3/
Grand total	228,000	240,000 r/	247,000 r/	262,000 r/	283,000 3/
Of which:					
Total primary	211,000	222,000 r/	226,000	236,000 r/	258,000
Total secondary	16,700	17,500	20,400	25,900	25,000
Total undifferentiated	200	200	200	100	--

e/ Estimated. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Whenever possible, total output has been separated into primary (from ores and concentrates) and secondary (tin metal recovered from old scrap). This table reflects metal production at the first measurable stage of metal output. Table includes data available through July 4, 2001.

3/ Reported figure.

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TITANIUM

By Joseph Gambogi

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2000, the titanium industry was engaged in a high level of mineral exploration and development activity. In addition to exploration activity, a number of expansion projects were underway in the mineral and titanium dioxide (TiO_2) pigment industries. In the titanium metal industry, rising demand in certain sectors allowed producers to use some of the excess capacity.

Approximately 95% of titanium is consumed as TiO_2 pigment, a pigment used in paints, paper, and plastics. The superiority of TiO_2 as a pigment is attributed to its high opacity and brightness. Titanium metal alloys are used in aerospace and other industries for their high strength-to-weight ratio and corrosion resistance.

Titanium is not naturally found in its metallic form but occurs in many mineral forms, such as oxides, titanates, and silicotitanates. As the ninth most abundant element in the Earth's crust, titanium is present in most rocks and soil. The titanium-bearing minerals that have significant economic importance include ilmenite, leucoxene, and rutile.

Legislation and Government Programs

The Defense National Stockpile Center met its target for the sale of titanium sponge from the U.S. Government stockpile. For fiscal year 2000, 4,540 metric tons (t) of titanium sponge was offered for sale. In accordance with section 3305 of the National Defense Authorization Act for Fiscal Year 1996 (Public Law 104-106), 250 t of titanium sponge was transferred to the Army's Tank and Automotive Command for use in the weight-reduction portion of the main battle tank upgrade program. Fiscal year 2000 is the fifth year of this program, which provides for transfers of up to 250 metric tons per year (t/yr) of titanium sponge to continue through fiscal year 2003. Although this material is provided to the Army without charge, the law specifies that the Army will pay the costs for transportation and handling (U.S. Department of Defense, 2000). At yearend 2000, the National Defense Stockpile held 26,300 t of titanium sponge.

Production

Mineral Concentrates.—Commercial forms of titanium mineral concentrates include ilmenite, leucoxene, rutile, slag, and synthetic rutile. Mining of titanium minerals is usually performed using surface methods. A dredge is often used for the recovery of titanium-mineral placer deposits. Gravity spirals are used for wet separation of heavy minerals (HM), while magnetic and high-tension separation circuits are used to separate the HM constituents. Ilmenite is often further beneficiated to produce synthetic rutile and titaniferous slag. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite. Titaniferous slag, with a TiO_2 content of up to 95%, is produced using a pyrometallurgical process.

Australia, Canada, India, Norway, and South Africa led the world's production of titanium mineral concentrate. U.S. mineral concentrate producers included E.I. du Pont de Nemours & Co. Inc. (DuPont), Kerr-McGee Chemical Corp., and Iluka Resources Inc. (a subsidiary of Iluka Resources Ltd.). DuPont's Trail Ridge mining operations in Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile that was used as a feedstock in DuPont's TiO_2 pigment operations. Iluka's mining operations in Green Cove Springs, FL, and Stony Creek, VA, produced both rutile and ilmenite concentrates. Kerr-McGee's operation in Mobile, AL, produced synthetic rutile from purchased ilmenite concentrate. Titanium slag was not produced in the United States.

Altair International Inc. was proceeding with feasibility

Titanium in the 20th Century

In the early 1900s, titanium minerals were primarily used in steelmaking for railways and as an arc stabilizer in electric lamps. Although little statistical data are available, domestic consumption of titanium minerals prior to 1920 was less than 2,000 metric tons per year, and domestic production was less than a few hundred tons per year. Composite pigments, containing approximately 25% titanium dioxide (TiO_2) and 75% barium sulfate, were not introduced to the commercial market until 1919. Commercial production of relatively pure TiO_2 pigments did not start until the early 1940s, and commercial production of titanium metal followed shortly thereafter.

In 2000, domestic consumption of titanium minerals was about 1.42 million tons (TiO_2 content). Imports were about 1.06 million tons (TiO_2 content), and roughly 0.3 million tons (TiO_2 content) of titanium minerals were produced. About 95% of titanium mineral concentrates produced was used in TiO_2 pigments, while the remainder was used in welding rod coatings and to manufacture metals, carbides, and chemicals. TiO_2 pigments produced in the United States, valued at about $2.6 billion, were used mainly in coatings (49.5%), plastics (21.3%), and paper (20.4%). Other uses of TiO_2 pigments (8.8%) in 2000 included catalysts, ceramics, coated textiles, floor coverings, printing ink, and roofing granules. The value of sponge metal consumed in the United States was about $170 million. Since its commercialization, the major end use for titanium metal has been in aerospace products. Other end uses include armor, chemical processing equipment, consumer goods, power generation equipment, marine goods, medical implants, and sporting goods.

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studies at its heavy mineral deposits near Camden, TN. In 2000, Altair began construction of a pilot mineral separation plant. If further studies are successful, Altair expects to produce 250,000 t to 300,000 t of a high TiO_2 mineral concentrate (North American Minerals News, 2000).

Iluka Resources studied the feasability of increasing capacity by 70% in four years at its Florida and Virginia mineral operations. The expansion project was expected to begin in 2001 (Iluka Resources Ltd., March 9, 2001, Annual report, accessed August 28, 2001, at URL http://www.iluka.com/files/annual%20report%202000.pdf).

Metal.—Titanium sponge is the rudimentary form of titanium metal. The initial production step involves the chlorination of titanium-containing mineral feedstocks to produce titanium tetrachloride ($TiCl_4$). The next step is usually based on the Kroll process where $TiCl_4$ is reduced with magnesium to form titanium sponge. In 2000, titanium sponge was produced in China, Japan, Kazakhstan, Russia, Ukraine, and the United States. U.S. producers of titanium sponge included The Alta Group, Allegheny Technologies Inc., and Titanium Metals Corp. At yearend, domestic operating capacity of titanium sponge was estimated to be 21,600 t/yr (table 2). Data on domestic production of titanium sponge have not been published in order to avoid disclosing company proprietary data.

U.S. production of ingot decreased by about 3% compared with that of 1999 (table 3). Titanium ingot is produced by melting titanium sponge or scrap or a combination of both usually with various other alloying elements, such as aluminum and vanadium. Electron beam, plasma, and vacuum arc reduction are the commercial melting methods used to produce ingot. In 2000, commercial ingot production capacity existed in France, Germany, Japan, Russia, the United Kingdom, and the United States.

Titanium mill products are produced from the drawing, forging, and rolling of titanium ingot or slab into products of various sizes and shapes. These mill products include billet, pipe and tube, plate, rod and bar, sheet and strip, wire, etc. Major producers of titanium mill products were located primarily in China, Europe, Japan, Russia, and the United States. More than 30 domestic companies were known to produce titanium mill products and castings from ingot and billet. In 2000, U.S. production of mill products increased by 7% compared with that of 1999.

Titanium castings are commonly produced by two techniques: investment casting and rammed graphite mold casting. In 2000, U.S. producers of titanium castings included Cast Alloys Inc., Coastcast Corp., Flowserve Corp., Howmet Corp., Precision Cast Parts Corp., Reactive Alloy Manufacturing Inc., RTI International Metals Inc., Selmet Inc., and Titanium Industries Inc.

Ferrotitanium is usually produced by induction melting of titanium scrap with iron or steel. U.S. producers of ferrotitanium included Galt Alloys Inc., Global Titanium Inc., and Shieldalloy Metallurgical Corp. The two standard grades of ferrotitanium contain 40% and 70% titanium. Data on production of ferrotitanium were not available.

Honeywell International Inc. announced it was investing $8.5 million in The Alta Group of its wafer fabrication materials division to meet the surge in demand for high purity titanium.Alta is the largest producer of high purity titanium ranging from 99.995% titanium to 99.9995% titanium. According to the company, demand had increased because of new semiconductor fabrication capacity coming online (Honeywell International Inc., November 1, 2000, Honeywell Electronic Materials (HEM) ALTA announces $8.5 million investment to meet demand for high purity titanium, accessed August 24, 2001, at URL http://www.electronicmaterials.com/mediakit/news/fb110100.htm).

TiO_2 Pigment.—TiO_2 pigment is produced from titanium mineral concentrates by either the chloride process or the sulfate process. In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid. Titanium hydroxide is precipitated by hydrolysis, filtered, and calcined. In the chloride process, rutile is converted to $TiCl_4$ by chlorination in the presence of petroleum coke. $TiCl_4$ is oxidized with air or oxygen at about 1,000° C, and the resulting fine-size TiO_2 is calcined to remove residual chlorine and any hydrochloric acid that may have formed in the reaction. Aluminum chloride is added to the $TiCl_4$ to assure that virtually all the titanium is oxidized in the rutile crystalline form.

Although either process may be used to produce pigment, the decision to use one process instead of the other is based on a number of factors, including raw material availability, freight, and waste disposal costs. In finishing operations, the crude form of the pigment is milled to produce a controlled distribution of particle size and surface treated or coated to improve its functional behavior in different media. Some typical surface treatments include alumina, silica, and organic compounds.

TiO_2 pigment produced by either process is categorized by crystal form as either anatase or rutile. Rutile-type pigment is less reactive with the binders in paint when exposed to sunlight than is the anatase type and is preferred for use in outdoor paints. Anatase pigment has a bluer tone than the rutile type, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing. Depending on the manner in which TiO_2 pigment is produced and subsequently finished, TiO_2 pigment can exhibit a range of functional properties, including opacity, durability, dispersion, and tinting.

World production of TiO_2 pigment was estimated to have increased slightly compared with that of 1999. In 2000, France, Germany, Japan, the United Kingdom, and the United States were the leading producing countries of TiO_2 pigment, while DuPont and Millennium Inorganic Chemicals Inc. were the largest corporate producers of TiO_2 pigment. U.S. production of TiO_2 pigment in 2000 was 1.40 million metric tons (Mt), a 3.6% increase compared with that of 1999. U.S. producers of TiO_2 pigment were DuPont, Millennium, Kerr-McGee, and Louisiana Pigment Co. LP (a NL Industries Inc. and Huntsman Corp. joint venture). In addition, TOR Minerals International Inc. produced a buff pigment from finely ground synthetic rutile (table 4). Capacity utilization for the domestic pigment industry was about 89%.

DuPont completed an expansion at its New Johnsonville, TN, TiO_2 pigment facility by adding a third line to the existing chloride route plant. New Johnsonville is the world's largest TiO_2 pigment facility (Industrial Minerals, 2000k). At yearend, capacity at New Johnsonville was estimated to be 380,000 t/yr.

Hitox Corp. of America changed its name to TOR Minerals International. TOR Minerals operates a facility in Corpus Christi, TX, where buff TiO_2 pigment is produced by fine grinding of synthetic rutile (Industrial Minerals, 2000b).

In April, Kerr-McGee completed the acquisition of Kemira Oyj's TiO_2 pigment facility at Savannah, GA. The Savannah

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facility included both a chloride-route plant and a sulfate-route plant. Kerr-McGee planned to upgrade these facilities in 2001 (Kerr-McGee Chemical Corp., April 6, 2000, Kerr-McGee completes acquisition of Kemira's Savannah plant, accessed August 21, 2001, at URL http://www.kerr-mcgee.com/news2000/040600.html).

Consumption

Mineral Concentrates.—Titanium mineral concentrates are primarily used as a feedstock for TiO_2 pigment production. About 5% of global mineral consumption is for miscellaneous uses such as ceramics, glass, steel, titanium metal, and welding rod coatings.

Based on TiO_2 content, domestic consumption of titanium minerals concentrates was 1.42 Mt, a 3% increase compared with that of 1999. Although consumption of ilmenite and slag decreased by 5%, consumption of rutile and synthetic rutile increased by 20% compared with that of 1999. On a gross weight basis, about 98% of the domestic consumption of titanium mineral concentrates was used to produce TiO_2 pigment.

Consumption data for titanium concentrates are developed by the U.S. Geological Survey from a voluntary survey of domestic operations. Of the 19 operations canvassed, 14 responded, representing 68% of the data in table 6. Data for nonrespondents were estimated based on prior-year consumption with some adjustments for present-year trends (table 6).

Metal.—Overall consumption of titanium sponge and scrap decreased by 8% compared with that of 1999. Scrap consumption by the titanium industry decreased by 15% compared with that of 1999, while sponge consumption was nearly unchanged. Scrap supplied a calculated 50% of ingot feedstock. Estimated U.S. mill product usage by application was as follows: aerospace, 60%, and nonaerospace uses, 40%. Nonaerospace uses included those in the consumer goods, marine, medical, oil and gas, pulp and paper, and specialty chemical industries. Reported consumption of titanium products in steel and other alloys increased by 3% compared with that of 1999 (tables 3, 7).

TiO_2 Pigment.—Global consumption of TiO_2 pigment was estimated to have increased moderately compared with that of 1999. In the United States, apparent consumption of TiO_2 pigment was about 1.15 Mt, virtually unchanged from 1999. The largest uses of TiO_2 pigment, based on TiO_2 pigment shipments in the United States, were paint and coatings (49.5%), paper (20.4%), and plastics (21.3%). Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

In the paint and coatings industry, TiO_2 pigment is used in architectural, equipment, and special-purpose applications and is widely used in white and color formulations. The TiO_2 content for paint and coatings varies significantly.

The plastics industry primarily consumes rutile-grade pigment. TiO_2 pigment is used in a variety of plastics applications. Primarily, TiO_2 pigment provides opacity and acts as a barrier against ultraviolet light degradation. TiO_2 pigment often is introduced as pelletized concentrate containing up to 50% by weight TiO_2 in a carrier resin; however, liquid and dry concentrates also are used by the industry. The TiO_2 content for plastics normally ranges from 3% to 25% by weight of the finished product.

TiO_2 pigment in paper products provides opacity and brightness. The paper industry consumes TiO_2 pigment as filler and in coatings. Paper products contain a high percentage of non-TiO_2 base minerals as filler material with the typical TiO_2 content less than 5% of the dry weight of paper. Anatase-grade pigment is preferred in the paper industry because it is less abrasive to papermaking machinery (tables 5, 8).

Stocks

On a TiO_2 content basis, yearend consumer inventories of titanium mineral concentrates decreased by 17% compared with those of 1999 (table 9). While consumer stocks of rutile and synthetic rutile rose by 5%, stocks of ilmenite and slag decreased by 24% compared with that of 1999.

On a gross weight basis, yearend producer stocks of TiO_2 pigment were about 141,000 t, a 3% increase compared with those of 1999. During the year, pigment stocks had fallen to a low of 124,000 t in September, then rose significantly in the last quarter.

Compared with those of 1999, industry stocks of titanium sponge and scrap decreased by 37% and 56%, respectively. Reduced consumption of ingot in 2000 resulted in a 33% increase in ingot stocks compared with those of 1999.

Prices

The yearend published price range for bulk rutile mineral concentrates was $470 to $500 per ton, a decrease of 6% compared with that of 1999. Meanwhile, the price range for bagged rutile concentrates commonly used in the welding rod coatings industry was $480 to $570 per ton, an increase of 2% compared with that of 1999. Owing in part to changes in currency exchange rates, yearend prices of ilmenite concentrates decreased by 3% compared with those of 1999. Published prices for titanium slag were not available. Based on U.S. Customs value of imports, however, prices for Canadian slag increased by 9%, while prices for South African slag were unchanged compared with those of 1999 (table 10).

Yearend published prices for anatase- and rutile-grade pigment were unchanged. Based on U.S. Customs value of imports, the average unit value of unfinished pigments and TiO_2 pigments with less than 80% TiO_2 content decreased by 8% and 6%, respectively. The average unit value of imported TiO_2 pigment with more than 80% TiO_2 content was unchanged.

The averaged yearend prices for ferrotitanium decreased by 66% compared with that of 1999. Average yearend prices unprocessed scrap turnings increased by 45% compared with those of 1999.

Foreign Trade

Mineral Concentrates.— The U.S. Census Bureau collects import and export data for mineral concentrates on a gross weight basis. Imports and exports of titaniferous iron ore from Canada (classified as ilmenite by the U.S. Census Bureau) are excluded from ilmenite statistics in this report. In 2000, the leading import sources of ilmenite were Australia (54%), Ukraine (31%), and India (8%). Imports of ilmenite for 2000 were 386,000 t, a slight decrease compared with those of 1999. Although imports of ilmenite from Australia decreased by 17%,

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imports from Ukraine increased by 14%. Owing to a significant drop in imports from Canada and South Africa, gross imports of titanium slag for 2000 fell to 533,000 t, a 21% decrease compared with those of 1999. Increases in natural rutile imported from Australia and South Africa helped to increase overall imports of natural rutile by 18%. Synthetic rutile imports, primarily from Australia, were 173,000 t, a 46% increase compared with imports in 1999 (table 12). Although small relative to imports, exports of titanium mineral concentrates were 18,900 t, a 102% increase compared with exports in 1999 (table 11).

Metal.—Imports of titanium metal are primarily in the form of titanium sponge (37%) and waste and scrap (39%). Compared with those of 1999, imports of unwrought metal, including sponge and waste and scrap, increased by 14% in 2000. Imports of wrought products and castings were unchanged. Although the United States was import reliant on unwrought titanium, the Nation was a net exporter of wrought products. In 2000, exports of wrought products were 35% of all metal exports. Total metal exports for 2000 decreased by 7% compared with those of 2000 (table 13).

TiO_2 Pigment.—Although the United States was a net exporter of TiO_2 pigment, a significant quantity of TiO_2 pigment was imported. During 1999, TiO_2 pigment imports increased by 13%, and the leading import sources of titanium pigment were Canada, France, Germany, Japan, and Spain. Compared with those of 1998, imports of titanium pigment containing more than 80% TiO_2 increased by 25% to 190,000 t; other titanium pigment increased by 58% to 9,320 t; and titanium oxide remained nearly unchanged at 25,700 t (table 14). Exports of TiO_2 pigment were 344,000 t, nearly unchanged compared with those of 1998. Exports of titanium oxide (unfinished pigment) were 39,000 t, a 7% decrease compared with those of 1998.

As has been the case for many years, the United States was a net exporter of TiO_2 pigments and oxides. In 2000, exports outpaced imports by more than 2 to 1. Compared with those of 1999, exports of TiO_2 pigment and oxides in 2000 increased by 21% on a gross weight basis. Meanwhile, imports of TiO_2 pigment and oxides decreased by 3%.

World Review

In 2000, Australia, Canada, India, Norway, and South Africa continued to lead the world's production of titanium mineral concentrates (table 15). Production of titanium mineral concentrates was estimated to be slightly higher compared with that of 1999.

Australia.—The Murray Basin in southeastern Australia has become an area of considerable interest to the titanium mineral industry. The basin covers a large area in New South Wales, Victoria, and South Australia, and numerous deposits are in various stages of exploration and development. According to one industry review, the indicated and inferred resources of contained heavy minerals in the Murray Basin are about 44 Mt (TZ Minerals International Pty. Ltd, 2000).

Basin Minerals Ltd., formerly Craton Resources NL, increased its estimate of inferred resources at its Douglas project in the Murray Basin. Inferred resources were estimated to be 20.8 Mt of concentrate. The Douglas project includes the Acapulco, Bondi East, Bondi, and Echo deposits. During 2000, Basin Minerals was conducting a prefeasibility study (Industrial Minerals, 2000a).

BeMax Resources NL reported the completion of a prefeasibility study on its Ginkgo heavy minerals project with Probo Mining Pty. Ltd. in the Murray Basin. According to BeMax, the study found no major impediments that would prevent the Ginkgo project from proceeding through a feasibility study. The indicated resource at Ginkgo was reported to be 252 Mt containing 2.8% heavy minerals (Industrial Minerals, 2001).

Murray Basin Minerals NL doubled the estimate of the heavy mineral resource at its Mercunda deposit in the Murray Basin. At yearend 2000, the resource was estimated to be 44 Mt of ore containing 3.4% heavy minerals. Feasibility studies were underway in 2000.

Murray Basin Titanium Pty. Ltd., a joint venture of RZM Pty. Ltd. and Sons of Gwalia Ltd., began construction of a mine site at its Wemen deposit in the Murray Basin. Mine plans included a separation plant at nearby Mildura. Production at the 30,000-t/yr plant was expected to begin in 2001. Other deposits under study included Cylinder, Birthday Gift, Karra, Jacks Tank North, Jacks Tank South, and Finnigans Tank (Industrial Minerals, 2000i).

Tiwest Pty. Ltd. announced plans to increase capacity at its TiO_2 pigment operation near Kwinana, Western Australia. Capacity is expected to increase to 95,000 t/yr (a 10% increase) in 2001. Tiwest is a 50-50 joint venture between KMCC Western Australia Pty Ltd., a subsidiary of Kerr-McGee Chemical LLC, and Ticor Resources Pty. Ltd. (Industrial Minerals, 2000g).

Brazil.—Millennium Inorganic Chemicals Inc. made plans to lower operating costs and improve ore recovery at the Titananio do Brazil S.A. operation near Mataraca, Paraiba. The project was expected to be completed by yearend 2001 and could raise ilmenite capacity at Mataraca to 120,000 t/yr, an increase of about 30,000 t/yr (Millennium Inorganic Chemicals Inc., 2000).

Canada.—Rio Tinto plc was in the process of increasing capacity at its upgraded slag (UGS) plant at Sorel, Quebec, to 250,000 t/yr (a 50,000 t/yr increase). Future expansions of its UGS plant are expected to increase capacity to 350,000 t/yr. Compared with the standard grade of slag from Sorel, UGS has a higher TiO_2 content and is suitable for use by chloride-route pigment producers (Rio Tinto plc, 2000).

Syncrude Canada Ltd. continued to investigate the recovery of heavy minerals from tailings of the Athabasca oil sands operations in northern Alberta. According to Syncrude, 220,000 t/yr of TiO_2 could be recovered. In 2000, Syncrude's research was focused on finding an alternative to calcining as a method for bitumen removal (J. Oxenford, Syncrude Canada Ltd., written commun. February 1, 2001).

NAR Resources Ltd. continued to study its heavy minerals deposit near Truro, Nova Scotia. At yearend 2000, the company was conducting a drilling program to confirm positive results of seismic studies and previous shallow drilling (NAR Resources Ltd., January 30, 2001, Quarterly report, accessed August 21, 2001, at URL http://www.nar-resources.com/Financial/quarter1.2001.pdf).

Germany.—Sachtleben Chemie GmbH neared completion of a 25% capacity expansion at its Duisberg sulfate-route TiO_2 pigment facility. The company planned to increase capacity to 100,000 t/yr through process improvements (Sachtleben Chemie GmbH, July 9, 2000, Capacity to increase to 100,000 tonnes titanium dioxide p.a., accessed August 21, 2001, at URL

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http://www.sachtleben.de/h/e/new/0970e.phtml?id=11,2).

India.—Kerala Minerals and Metals Ltd. made plans for a 2-year project to increase titanium mineral and pigment capacities at its Charava complex. A new separation plant is expected to increase ilmenite production capacity to 300,000 t/yr. By 2002, synthetic rutile capacity will be increased to 130,000 t/yr from 30,000 t/yr, and TiO_2 pigment capacity is expected to be increased to 60,000 t/yr from the current [2000] 22,000 t/yr (Industrial Minerals, 2000j).

Iscor and Mineral Deposits Ltd. formed an agreement to study several heavy mineral sands deposits in Tamil Nadu. The Kudiraimozhi deposit is located about 90 kilometers southwest of Tuticorin, with an estimated resource of 23 Mt of ilmenite and 1.3 Mt of rutile. Two other deposits under study include one near Sattankulam and another stretching between the cities of Navaladi and Sattankulam (Industrial Minerals, 2000h).

Kazakhstan.—Ust-Kamengorsk Titanium and Magnesium Combine (UKTMC) commissioned a slag plant at its titanium metal facility in Ust-Kamengorsk (Analysis and Strategic Research Center, October 2000, N. Nazarbayev visited eastern Kazakhstan oblast, accessed October 24, 2001, via URL http://www.president.kz/articles/News/News.asp?lng=&art=news2001_october). UKTMC planned to commission its Satpayev ilmenite mine near Bekmir in 2001 (Interfax International Ltd., 2000).

Kenya.—Tiomin Resources Inc. submitted an environmental impact assessment (EIA) for its Kwale mineral sands project to the Ministry of Environment and Natural Resources. Approval of the EIA was pending at yearend (Tiomin Resources Inc., March 31, 2001, Poised for development—2000 annual report, accessed August 21, 2001, at URL http://www.tiomin.com/i/pdf/tio-ar00.pdf).

Malaysia.—Huntsman Tioxide was in the process of increasing capacity at its Teluk Kalung sulfate-route TiO_2 pigment facility. When completed, capacity will be expanded to 56,000 t/yr (a 6,000 t/yr increase) through process improvements (Hunstman Corp, March 31, 2000, Huntsman Tioxide announces capacity increases, accessed October 24, 2001, at URL http://www.huntsman.com/tioxide/ShowPage.cfm?PageID=925&News_ID=647).

TOR Minerals acquired Malaysian Titanium Corp. (MTC). MTC's Ipoh facility is the sole supplier of synthetic rutile for TOR Minerals' buff TiO_2 pigment facility in Corpus Christi, TX (Industrial Minerals, 2000c).

Mozambique.—Kenmare Resources plc acquired the wet separation plant from BHP Minerals' defunct Beenup mining operation in Australia. The plant was shipped to Kenmare's Moma Mineral Sands project in Mozambique. Kenmare expects to begin production by yearend 2002. Capacity at Moma is projected to reach 600,000 t/yr of ilmenite and 16,500 t/yr of rutile (Industrial Minerals, 2000e).

WMC Ltd., Southern Mining Corp., and the state-owned Industrial Development Corp. were proceeding with the development of the Corridor Sands project in Mozambique. In 2000, a feasibility study concluded there were no technical issues to be resolved and the project could proceed. Reserves were estimated to be 45 Mt of ilmenite (Industrial Minerals, 2001).

Netherlands.—In May, Kerr-McGee completed the acquisition of Kemira's TiO_2 pigment plant at Botlek. Capacity at Botlek is based on chloride route technology and is reported to be 56,000 t/yr (Kerr-McGee Chemical Corp., May 4, 2000, Kerr-McGee completes acquisition of Botlek pigment plant, accessed August 21, 2001, at URL http://www.kerr-mcgee.com/news2000/050400.html).

Saudi Arabia.—Kerr-McGee sold its 25% interest in National Titanium Dioxide Co. Ltd., also known as the Cristal joint-venture, to the remaining joint venture partners Shairco for Trading and Contracting, the National Industrialization Co., and Gulf Investment Corp. Cristal is the only TiO_2 pigment producer in Saudi Arabia with 70,000 t/yr of chloride-route capacity (Industrial Minerals, 2000f).

South Africa.—Iscor Ltd. was proceeding with plans to develop its Hillendale deposit near Richards Bay. The company planned to begin mining operations in 2001. In the second phase of the project, Iscor hopes to construct a 250,000-t/yr slag plant at nearby Empangeni. Hillendale reserves are estimated to contain about 4 Mt of heavy minerals (Industrial Minerals, 2000d).

Spain.—Huntsman Corp. was in the process of increasing capacity at its Huelva sulfate-route TiO_2 pigment facility. When completed, capacity will be expanded to 90,000 t/yr (a 17,000 t/yr increase) through process improvements (Huntsman Tioxide, March 9, 2001, Huntsman Tioxide approves $40M expansion of Huelva, Spain plant, accessed August 21, 2001, at URL http://www.huntsman.com/tioxide/ShowPage.cfm?PageID=925&News_ID=642).

United Kingdom.—In September, Huntsman Corp. announced plans to proceed with the construction of a new chloride-route TiO_2 pigment plant at its Greatham facility. The new plant is expected to be completed in 2002 and is expected to bring capacity up to 100,0000 t/yr (Huntsman Tioxide, September 22, 2000, Huntsman Tioxide announces go-ahead for new £50 million plant at Greatham, Deeside, UK, accessed August 21, 2001, at URL http://www.huntsman.com/tioxide/ShowPage.cfm?PageID=925&News_ID=644).

Outlook

Demand for TiO_2 pigment is expected to remain near its current level in the coming year. Over the next 5 years, global economic growth is expected to increase TiO_2 pigment consumption by 3% to 4% per year. Because approximately 95% of all titanium minerals are consumed to produce TiO_2 pigment, consumption of titanium minerals is expected to follow a similar trend.

In the titanium metal industry, the resumption of some aerospace orders is expected to increase demand for some titanium metal products over the coming year. An overall economic slowdown, however, may result in negative growth within the industry. Long-term growth in passenger traffic and nonaerospace markets is expected to result in a 5% per year demand growth over the next decade.

References Cited

Industrial Minerals, 2000a, Douglas minsands moves to feasibility: Industrial Minerals, no. 398, November, p. 9.

———2000b, HiTox name change: Industrial Minerals, no. 393, June, p. 80.

———2000c, HiTox/MTC purchase: Industrial Minerals, no. 391, April, p. 71.

———2000d, Iscor gives go-ahead to Hillendale minsands: Industrial Minerals, no. 392, May, p. 12, 15.

———2000e, Kenmare buys second Beenup plant: Industrial Minerals, no. 393, June, p. 15.

———2000f, Kerr McGee divests Cristal interests: Industrial Minerals, no. 398, November, p. 16.

———2000g, Kwinana TiO_2 capacity hike for Kerr-McGee: Industrial

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Minerals, no. 397, October, p. 9.
———2000h, MDL and Iscor form alliance for Tamil Nadu minsands: Industrial Minerals, no. 399, December, p. 12.
———2000i, Murray Basin project nears development: Industrial Minerals, no. 399, December, p. 9-11.
———2000j, State cabinet clears KMML TiO_2 expansion: Industrial Minerals, no. 390, March, p. 20.
———2000k, Third TiO_2 line for DuPont at Tennessee: Industrial Minerals, no. 391, April, p. 16-17.
———2000l, WMC proceeds in Corridor Sands project: Industrial Minerals, no. 399, December, p. 13.
———2001, Ginko minsands: Industrial Minerals, no. 400, January p. 65.
Interfax International Ltd., 2000, Kazakh titanium plans ups metals production: Mining & Metals Report, v. 9, issue 41 (446), October 6-12, p. 17.
Millennium Inorganic Chemicals Inc., 2000, Millennium Inorganic Chemicals to invest in Paraiba (Brazil) mine upgrade: Hunt Valley, MD, Millennium Inorganic Chemicals Inc. press release, February 2, 1 p.
North American Minerals News, 2000, Altair engages Rothschild for Tennessee TiO_2 project: North American Minerals News, no. 58, March, p. 4.
Rio Tinto plc, 2000, Rio Tinto plc.—Annual report: Bristol, United Kingdom, Rio Tinto plc, March 6, 24 p.
TZ Minerals International Pty. Ltd, 2000, The Murray Basin —Potential for development: Mineral Sands Report, no. 59, September, p. 4-6.
U.S. Department of Defense, 2000, Strategic and critical materials report to Congress: Washington, DC, U.S. Department of Defense, January 16, 54 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Force, E.R., and Lynd, L.E., 1984, Titanium mineral resources of the United States—Definitions and documentation, contributions to the geology of mineral deposits: Bulletin 1558-B, 11 p.
Recycling—Metals. Ch. in Minerals Yearbook, annual.
Titanium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Titanium. Ch. in Metal Prices in the United States through 1998, 1999.
Titanium. International Strategic Minerals Inventory Summary Report, Circular 930-G, 1988.
Titanium. Mineral Industry Surveys, quarterly.
Titanium and Titanium Dioxide. Ch. in Mineral Commodity Summaries, annual.
Titanium Mineral Concentrates. Ch. in Mineral Commodity Summaries, annual.

Other

American Metal Market, daily.
Chemical Engineering, biweekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
Geology of titanium-mineral deposits, Geological Society of America Special Paper 259, 1991.
Industrial Minerals (London), monthly.
Inorganic Chemicals. U.S. Census Bureau Current Industrial Reports, quarterly and annual.
International Titanium Association (Broomfield, CO).
Japan Titanium Society (Tokyo, Japan).
Metal Bulletin (London), semiweekly.
Mining Engineering, monthly.
Mining Magazine, monthly and weekly.
Mining Journal (London), monthly and weekly.
Platts Metals Week, weekly.
Roskill Information Services Ltd. (London).
Titanium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT TITANIUM STATISTICS 1/

(Metric tons, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Ilmenite and titanium slag:					
Imports for consumption	939,000	952,000	1,010,000	1,070,000	918,000
Consumption	1,400,000 2/	1,520,000 2/	1,300,000 3/	1,280,000 3/	1,250,000 3/
Rutile concentrate, natural and synthetic:					
Imports for consumption	324,000	336,000	387,000	344,000	438,000
Consumption	398,000	489,000	421,000	494,000	537,000
Sponge metal:					
Imports for consumption	10,100	16,100	10,900	6,000	7,240
Consumption	28,400	32,000	28,200	18,100	18,200
Price, December 31 dollars per pound	4.25-4.50	4.25-4.50	4.25-4.50	3.70-4.80	3.70-4.80
Titanium dioxide pigment:					
Production	1,230,000	1,340,000	1,330,000	1,350,000	1,400,000
Imports for consumption	167,000	194,000	200,000	225,000	218,000
Consumption, apparent 4/	1,070,000	1,130,000	1,140,000	1,160,000	1,150,000
Price, December 31:					
Anatase dollars per pound	1.06-1.08	1.01-1.03	0.96-0.98	0.92-0.94	0.92-0.94
Rutile do.	1.08-1.10	1.04-1.06	0.97-0.99	0.99-1.02	0.99-1.02
World production:					
Ilmenite concentrate 5/	4,380,000 r/	4,470,000 r/	4,530,000 r/	4,160,000 r/	4,770,000 e/
Rutile concentrate, natural 5/	366,000	406,000	441,000	359,000 r/	417,000 e/
Titaniferous slag	1,830,000	1,950,000	2,050,000	2,050,000	2,070,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Includes consumption to produce synthetic rutile.

3/ Excludes consumption used to produce synthetic rutile.

4/ Production plus imports minus exports plus stock decrease or minus stock increase.

5/ Excludes U.S. production data to avoid disclosing company proprietary data.

TABLE 2
U.S. TITANIUM METAL PRODUCTION CAPACITY IN 2000 1/ 2/

(Metric tons)

		Yearend capacity	
Company	Plant location	Sponge	Ingot 3/
Allegheny Technologies Inc.	Albany, OR	6,800	10,900
Do.	Monroe, NC	--	11,800
Do.	Richland, WA	--	10,000
Alta Group	Salt Lake City, UT	340	--
Howmet Corp.	Whitehall, MI	--	3,200
Lawrence Aviation Industries Inc.	Port Jefferson, NY	--	1,400
RMI Titanium Co.	Niles, OH	--	16,300
Titanium Metals Corp.	Henderson, NV	14,500	13,000
Do.	Morgantown, PA	--	24,500
Do.	Vallejo, CA	--	450
Total		21,600	91,600

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Operating capacity based on 7-day-per-week full production.

3/ Includes electron-beam, plasma, and vacuum-arc-reduction capacity.

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TABLE 3
COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND 1/

(Metric tons)

Component	1999	2000
Production:		
Ingot	40,700	39,600
Mill products	24,200	25,900
Exports:		
Sponge	807	1,930
Waste and scrap	8,130	5,060
Other unwrought 2/	2,470	3,200
Wrought products and castings 3/	5,260	5,380
Total	16,700	15,600
Imports:		
Sponge	6,000	7,240
Waste and scrap	6,870	7,550
Other unwrought 2/	1,610	1,790
Wrought products and castings 3/	2,910	2,900
Total	17,400	19,500
Stocks, yearend:		
Government, sponge (total inventory)	31,200	26,300
Industry:		
Sponge	7,970	5,010
Scrap	9,450	5,150
Ingot	5,180	6,910
Reported consumption:		
Sponge	18,100	18,200
Scrap	21,900	18,500
Receipts:		
Home	11,600	5,820
Purchased	14,500	15,600
Ingot	30,800	27,400
Mill products (net shipments):	21,600	23,600
Forging and extrusion billet	10,100	12,500
Plate, sheet, strip	7,170	7,200
Rod, bar, fastner stock, wire	3,240	3,350
Other 4/	1,100	548
Castings (shipments)	757	658

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes billet, blooms, ingot, powder, sheet bar, slab, and other.
3/ Includes castings, foil, pipes, profiles, tubes, other wrought and articles of titanium not elsewhere specified or included.
4/ Data for extrusions, (other than tubing), pipe and tubing, and other have been combined to avoid disclosing company proprietary data.

TABLE 4
CAPACITIES OF U.S. TITANIUM DIOXIDE PIGMENT PLANTS ON DECEMBER 31, 2000 1/ 2/ 3/

(Metric tons per year)

		Yearend capactiy		
Company	Plant location	Sulfate process	Chloride process	Total
E.I. du Pont de Nemours & Co. Inc.	De Lisle, MS	--	280,000	280,000
Do.	Edgemoor, DE	--	154,000	154,000
Do.	New Johnsonville, TN	--	380,000	380,000
Kemira, Inc.	Savannah, GA	60,000	100,000	160,000
Kerr-McGee Chemical Corp.	Hamilton, MS	--	190,000	190,000
Louisiana Pigment Co. LP	Lake Charles, LA	--	120,000	120,000
Millennium Inorganic Chemicals Inc.	Ashtabula, OH	--	198,000	198,000
Do.	Baltimore, MD	44,000	51,000	95,000
Total		104,000	1,470,000	1,580,000

-- Zero.
1/ Operating capacity based on 7-day-per-week full production.
2/ Table does not include TOR Minerals International's Corpus Christi, TX, production capacity of about 16,400 metric tons per year of buff TiO_2 pigments that is produced by refining and fine grinding of synthetic rutile.
3/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 5
COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND 1/

(Metric tons, unless otherwise specified)

	1999		2000	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Production 2/	1,350,000	1,300,000 e/	1,400,000	1,320,000 e/
Shipments: 3/				
Quantity	1,430,000	1,350,000	1,470,000	1,380,000
Value thousands	$2,700,000	$2,700,000	$2,760,000	$2,760,000
Exports	384,000	368,000 e/	464,000	436,000 e/
Imports for consumption	225,000	216,000 e/	218,000 e/	205,000 e/
Stocks, yearend	137,000	130,000 r/	141,000 e/	133,000 e/
Consumption, apparent 4/	1,160,000	1,110,000 e/	1,150,000 e/	1,090,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Excludes production of buff pigment.

3/ Includes interplant transfers.

4/ Production plus imports minus exports plus stock decrease or minus stock increase.

Source: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
U.S. CONSUMPTION OF TITANIUM CONCENTRATES 1/

(Metric tons)

	1999		2000	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Ilmenite and titanium slag: 2/ 3/				
Pigments	1,270,000	NA	1,240,000	NA
Miscellaneous 4/	13,400	NA	13,900	NA
Total	1,280,000	963,000	1,250,000	919,000
Rutile, natural and synthetic:				
Pigments	469,000	NA	513,000	NA
Miscellaneous 4/	25,800	NA	24,100	NA
Total	494,000	413,000	537,000	497,000
Total concentrates:				
Pigments	1,740,000	NA	1,750,000	NA
Miscellaneous 4/	39,100	NA	38,000	NA
Total	1,780,000	1,380,000	1,790,000	1,420,000

NA Not available.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

3/ Excludes ilmenite used to produce synthetic rutile.

4/ Includes alloys, carbide, welding-rod coatings and fluxes, ceramics, chemicals, glass fibers, and titanium metal.

TABLE 7
U.S. CONSUMPTION OF TITANIUM PRODUCTS IN STEEL AND OTHER ALLOYS 1/ 2/

(Metric tons)

	1999	2000
Carbon steel	3,630	3,690
Stainless and heat-resisting steel	1,760	1,520
Other alloy steel (includes HSLA and tool steel)	676	777
Total steel	6,060	5,990
Superalloys	681	918
Alloys, other than above	586	684
Miscellaneous and unspecified	79	8
Total consumption	7,410	7,600

1/ Includes ferrotitanium, titanium scrap, and other titanium additives.

2/ Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 8
U.S. DISTRIBUTION OF TITANIUM PIGMENT SHIPMENTS,
TITANIUM DIOXIDE CONTENT, BY INDUSTRY 1/

(Percent)

Industry	1999	2000
Coated fabrics and textiles	0.2	0.2
Paint, varnish, lacquer	50.2	49.5
Paper	20.0	20.4
Plastics	21.0	21.3
Printing ink	0.5	0.5
Rubber	0.8	1.0
Other 2/	7.3	7.1
Total	100.0	100.0

1/ Excludes exports.
2/ Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, and paper; also includes shipments to distributors.

TABLE 9
U.S. STOCKS OF TITANIUM CONCENTRATES AND PIGMENT, DECEMBER 31, 2000 1/

(Metric tons)

	1999		2000	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Concentrates: 2/				
Ilmenite and titanium slag	489,000	343,000	337,000	262,000
Rutile, natural and synthetic	106,000	96,400	109,000	101,000
Titanium pigment 3/	137,000	130,000 e/	141,000	133,000 e/

e/ Estimated.
1/ Data are rounded to no more than three significant digits.
2/ Consumer stocks.
3/ Data from U.S. Census Bureau. Producer stocks only.

TABLE 10
PUBLISHED PRICES OF TITANIUM CONCENTRATES AND PRODUCTS

		1999	2000
Concentrates:			
Ilmenite, f.o.b. Australian ports	dollars per metric ton	90.00-103.00	83.00-105.00
Rutile, bagged, f.o.b. Australian ports	do.	500.00-530.00	480.00-570.00
Rutile, bulk, f.o.b. Australian ports	do.	435.00-510.00	470.00-500.00
Titanium slag, 80% TiO_2, Canada 1/	do.	390.00	349.00
Titanium slag, 85%TiO_2, South Africa 1/	do.	406.00	407.00
Metal:			
Sponge	dollars per pound	3.70-4.80	3.70-4.80
Ferrotitanium	do.	2.20-2.40	.75-.80
Scrap, turnings, unprocessed	do.	1.08-1.12	1.55-1.63
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do.	.92-.94	.92-.94
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do.	.99-1.02	.99-1.02

1/ Unit value based on U.S. imports for consumption.

Sources: American Metal Market, American Paint and Coatings Journal, Chemical Market Reporter, Industrial Minerals (London), Metal Bulletin, Platt's Metals Week, and industry contacts.

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TABLE 11
U.S. EXPORTS OF TITANIUM PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Metal:				
Unwrought:				
Sponge	807	$5,750	1,930	$11,400
Waste and scrap	8,130	11,700	5,060	12,700
Other unwrought:				
Billet	327	8,120	263	6,320
Blooms and sheet bars	848	25,900	1,460	51,700
Ingot	683	12,600	829	11,900
Other	616	11,800	649	12,600
Wrought products and castings:				
Bars and rods	1,870	62,800	2,400	81,000
Other	3,390	176,000	2,980	172,000
Total metal	16,700	314,000	15,600	360,000
Ores and concentrates	9,380	5,350	18,900	7,920
Pigment and oxides:				
80% or more titanium dioxide and other titanium dioxide pigments	344,000	558,000	423,000	703,000
Titanium oxides	39,300	69,000	41,000	80,500
Total	384,000	627,000	464,000	784,000

1/ Data are rounded to no more than three significant digits, may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATES, BY COUNTRY 1/

Concentrate and country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Ilmenite:				
Australia	252,000	$21,100	209,000	$23,100
India	30,100	2,450	29,400	2,560
Malaysia	--	--	26,000	1,240
Norway	100	8	--	--
Sierra Leone	2,600	153	--	--
Ukraine	106,000	9,130	121,000	10,300
Total	391,000	32,800	386,000	37,200
Titanium slag:				
Canada	208,000	78,200	123,000	52,600
Norway	10,000	3,690	10,000	3,800
South Africa	459,000	183,000	400,000	162,000
Other	--	--	30	27
Total	678,000	265,000	533,000	219,000
Rutile, natural:				
Australia	72,500	28,600	113,000	47,600
Canada	22,600	19,100	1,080	724
Korea, Republic of	34 r/	44 r/	172	223
Siera Leone	4,730	1,180	--	--
South Africa	125,000	50,600	140,000	58,500
Ukraine	--	--	10,000	3,920
Other 2/	78 r/	103 r/	4	8
Total	225,000	99,700	265,000	111,000
Rutile, synthetic:				
Australia	114,000	37,000	159,000	51,600
India	--	--	9,050	3,750
Malaysia	4,230	2,780	5,700	3,080
Other	95 r/	69 r/	45	61
Total	119,000	39,800	173,000	58,400
Titaniferous iron ore, Canada 4/	10,700	2,620	88,200	4,890

See footnotes at end of table.

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TABLE 12--Continued
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATES, BY COUNTRY 1/

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Data being verified by the U.S. Census Bureau.
3/ Less than 1/2 unit.
4/ Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel-furnance flux.

Source: U.S. Census Bureau. Data adjusted by the U.S. Geological Survey. Titaniferous iron ore from Canada is classified as ilmenite under the Harmonized Tariff Schedule of the United States.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY 1/

	1999		2000	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought:				
Sponge:				
Japan	2,070	$17,500	3,790	$29,200
Kazakhstan	814	5,540	2,170	13,500
Russia	2,570	16,500 r/	1,200	6,780
United Kingdom	417	2,210	--	--
Other	135 r/	441 r/	77	381
Total	6,000	42,200	7,240	49,900
Waste and scrap:				
Belgium	293	547	280	568
Canada	264	409	155	373
France	955	2,160	1,220	3,910
Germany	479	1,380	693	2,350
Italy	586	1,960	491	1,550
Japan	1,790	6,420	1,760	5,760
Russia	692	1,940	692	2,280
Sweden	177	279	251	881
United Kingdom	1,090	2,840	1,360	4,670
Other	540 r/	1,610	648	1,760
Total	6,870	19,500	7,550	24,100
Ingot and biller:				
China	347	4,760	13	188
Japan	134	1,450	105	3,570
Russia	787	10,600	1,240	14,800
United Kingdom	113	3,660	76	3,710
Other	--	--	103	976
Total	1,380	20,400	1,540	23,200
Powder	224	1,170	250	2,610
Other: 2/				
Canada	(3/)	11	17	102
Japan	1	260	(3/)	130
Russia	9	92	--	--
United Kingdom	--	--	4	87
Other	(3/) r/	60 r/	2	79
Total	10	423	23	398
Wrought products and castings: 4/				
Canada	124	3,630	123	3,170
China	133	3,180	59	1,220
Italy	253	5,600	113	2,010
Japan	566	17,200	643	15,700
Russia	1,520	30,300	1,510	24,800
United Kingdom	118	6,240	152	4,800
Other	197 r/	7,920 r/	300	8,950
Total	2,910	74,100	2,900	60,600
Ferrotitanium and ferrosilicon-titanium	4,750	8,620	6,050	15,900

See footnotes at end of table.

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TABLE 13--Continued
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY 1/

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes blooms, sheet, bars, slabs, and other unwrought.
3/ Less than 1/2 unit.
4/ Includes bars, castings, foil, pipes, plates, profiles, rods, sheet, strip, tubes, wire, and other.

Source: U.S. Census Bureau.

TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENTS, BY COUNTRY 1/

	1999		2000	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
80% or more titanium dioxide:				
Australia	6,230	$11,600	20	$32
Belgium	3,740	6,450	3,030	5,410
Canada	75,200	129,000	64,000	111,000
China	5,650	6,660	5,910	7,450
Finland	3,220	6,650	1,870	4,230
France	6,080	10,300	5,760	9,290
Germany	25,900	52,800	24,100	50,300
Italy	3,380	5,830	8,400	13,900
Japan	12,900	28,000	6,920	18,900
Norway	4,310	7,580	6,290	11,000
Poland	441	660	440	778
Singapore	3,390	5,500	3,010	5,300
Slovenia	2,700	4,560	2,730	5,040
South Africa	5,380	8,790	7,690	13,800
Spain	14,000	25,100	15,700	27,300
United Kingdom	4,060	6,890	3,980	6,770
Other	13,200	20,700	20,600	30,300
Total	190,000	337,000	180,000	320,000
Other titanium dioxide:				
Belgium	1,870	4,450	2,610	6,110
Canada	3,480	5,850	3,110	5,560
Germany	2,400	8,090	1,670	4,930
United Kingdom	171	1,220	81	256
Other	1,400 r/	3,930 r/	1,280	3,870
Total	9,320	23,500	8,760	20,700
Titanium oxide:				
Australia	3,380	5,930	--	--
Belgium	1,660	2,720	1,440	2,400
Canada	487	812	--	--
China	3,470	3,670	6,350	7,040
Czech, Republic of	2,240	3,960	2,030	3,660
France	7,850	11,900	7,180	10,900
Germany	809	1,830	935	2,140
Japan	653	7,130	630	6,640
Poland	1,300	2,200	2,520	4,540
Ukraine	2,020	2,700	7,050	8,800
Other	1,860 r/	2,970 r/	830	1,380
Total	25,700	45,900	29,000	47,500
Grand total	225,000	406,000	218,000	389,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 15
TITANIUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Concentrate type and country	1996	1997	1998	1999	2000 e/
Ilmenite and leucoxene: 3/					
Australia:					
Ilmenite	2,028,000	2,233,000	2,379,000	1,990,000	2,156,000 4/
Leucoxene	33,000	32,000	30,000	32,000	27,000 4/
Brazil 5/	97,955	97,174	103,000	96,000 r/ e/	96,000
China e/	165,000	170,000	175,000	180,000	185,000
Egypt	124,000	125,000	125,000	130,000	125,000 4/
India e/	330,000	332,000	378,000	378,000	380,000
Malaysia	244,642	167,504	124,689	127,695	110,000
Norway e/	746,583 4/	750,000	590,000	600,000 r/	610,000
Sri Lanka	62,810	17,970	34,118	-- r/	--
Ukraine	500,000 r/ e/	500,000 r/ e/	507,435 r/	536,542 r/	576,749
United States	W	W	W	W	400,000 6/
Vietnam e/	50,000	50,000	80,000	91,000 r/	109,000
Total	4,380,000 r/	4,470,000 r/	4,530,000 r/	4,160,000 r/	4,770,000
Rutile:					
Australia	180,000	214,000	241,000	190,000	237,000 4/
Brazil	2,018	1,742	1,800 e/	4,300 r/ e/	4,000
India e/	15,000	14,000	16,000	16,000	17,000
South Africa e/	115,000	123,000	130,000	100,000 r/	100,000
Sri Lanka	3,532	2,970	1,930	-- r/	--
Ukraine e/	50,000	50,000	50,000	49,000 r/	58,600
United States	W	W	W	W	(7/)
Total	366,000	406,000	441,000	359,000 r/	417,000
Titaniferous slag: e/ 8/					
Canada	825,000	850,000	950,000	950,000	950,000
South Africa	1,000,000	1,100,000	1,100,000	1,100,000	1,120,000
Total	1,830,000	1,950,000	2,050,000	2,050,000	2,070,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

1/ Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 13, 2001.

3/ Ilmenite is also produced in Canada and South Africa, but this output is not included here because most of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

4/ Reported figure.

5/ Excludes production of unbeneficiated anatase ore.

6/ Includes rutile to avoid revealing company proprietary data. Rounded to one significant digit.

7/ Included with ilmenite to avoid revealing company proprietary data; not included in "Total."

8/ Slag is also produced in Norway, but this output is not included under "Titaniferous slag" to avoid duplicative reporting.

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TUNGSTEN

By Kim B. Shedd

Domestic survey data and tables were prepared by Jason T. Collins, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Tungsten is a whitish-gray metal with many unique properties and a wide variety of uses (see Tungsten in the 20th Century section of this report). During 2000, U.S. demand for tungsten increased. Worldwide, the availability of tungsten raw materials from China was limited by export quotas, exports of stockpiled Russian tungsten materials decreased, and prices increased. The important U.S. and world tungsten statistics for 2000 and the previous 4 years are listed in table 1.

Most data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers. Unless otherwise specified, all statistics in this report are in metric tons of contained tungsten.

Tungsten prices and many tungsten statistics from other sources are quoted in units of tungsten trioxide (WO_3). The short ton unit, which is used in the United States, is 1% of a short ton (20 pounds), and WO_3 is 79.3% tungsten. A short ton unit of WO_3, therefore, equals 20 pounds of WO_3 and contains 7.19 kilograms (kg) (15.86 pounds) of tungsten. The metric ton unit, which is used in most other countries, is 1% of a metric ton (10 kg). A metric ton unit of WO_3, therefore, equals 10 kg of WO_3 and contains 7.93 kg (17.48 pounds) of tungsten.

Legislation and Government Programs

As a result of reviews conducted by the International Trade Administration, U.S. Department of Commerce, and the U.S. International Trade Commission during 1999, the 151% duty on imports of tungsten ore concentrates from China was revoked effective January 1, 2000 (International Trade Administration, 1999; U.S. International Trade Commission, 1999).

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, continued its negotiated sales of tungsten materials from the National Defense Stockpile (NDS). Ten bid offerings were held during calendar year 2000—three for tungsten ores and concentrates and seven for ferrotungsten, tungsten carbide powder, and/or tungsten metal powder. As shown in table 2, 2,610 metric tons (t) of tungsten contained in ores and concentrates, ferrotungsten, tungsten metal powder, and tungsten carbide powder was sold during the calendar year. During fiscal year 2000 (October 1, 1999, through September 30, 2000), 2,320 t of contained tungsten was sold; this represented 94% of the maximum amount available for sale in the Annual Materials Plan (AMP). Of the tungsten materials sold prior to September 30, 2000, the following quantities, in metric tons of contained tungsten, had not been shipped by the end of the 2000 fiscal year: tungsten ores and concentrates, 1,560; tungsten carbide powder, 309; and ferrotungsten, 123 (U.S. Department of Defense, 2001, p. 48). The quantities of tungsten materials remaining in the stockpile at the end of the calendar year, including those committed for sale and pending shipment, are listed in tables 1 and 2.

The AMP for fiscal year 2001 (October 1, 2000, through September 30, 2001) maintained the maximum quantities of tungsten materials that could be sold, in metric tons of contained tungsten, at the following levels: tungsten ores and concentrates, 1,810; tungsten carbide powder, 454;

Tungsten in the 20th Century

In 1900, the main use of tungsten was to make ferrotungsten, which was used to produce steel. Lesser amounts of tungsten were used to make aluminum-tungsten alloys and tungsten-copper alloys, which were used to make propeller blades. Sodium tungstate was used to make fabric colorfast or flame resistant, and because of its ability to fluoresce, calcium tungstate was used to make screens for X-ray apparatus. Tungsten chemicals were also used as pigments for coloring glass. Although some tungsten was mined in the United States in 1900, most of the U.S. supply was imported. The leading producers of tungsten ores were Australia; Austria-Hungary, at the time a dual monarchy in Central Europe; England; Germany; and Saxony, an independent kingdom at the time that is now part of Germany. Few statistics on tungsten production and use are available for 1900. World production of tungsten concentrates was probably less than 1,500 metric tons contained tungsten. U.S. production was estimated to be approximately 20 tons contained tungsten.

In 2000, tungsten was used in many diverse commercial, industrial, and military applications. The largest use was as tungsten carbide in cemented carbides, which were wear-resistant materials used by the metalworking, mining, and construction industries. Tungsten metal wires, electrodes, and contacts were used in lighting, electronic, electrical, heating, and welding applications. Tungsten was also used to make heavy metal alloys for armaments, heat sinks, radiation shielding, and weights and counterweights; superalloys for turbine blades; tool steels; and wear-resistant alloy parts and coatings. Tungsten composites were used as a substitute for lead in bullets and shot. Tungsten chemicals were used in catalysts, inorganic pigments, high-temperature lubricants, and semiconductors. The U.S. apparent consumption of all tungsten materials was 14,300 tons in 2000. No tungsten was mined in the United States. U.S. tungsten supply comprised imports, tungsten-bearing scrap, releases from industry stocks, and sales of excess tungsten materials from the National Defense Stockpile. World production of tungsten concentrates was approximately 37,400 tons contained tungsten. More than three-fourths of this production was from China. Austria, Bolivia, Portugal, and Russia were also significant producers of tungsten concentrates.

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ferrotungsten, 136; and tungsten metal powder, 68 (Defense National Stockpile Center, 2000a). In October, the DNSC proposed a change in its sales program for tungsten ores and concentrates. DNSC planned to sell ores and concentrates under long-term contracts. The entire AMP quantity would be offered at one time, with an option to purchase additional quantities during the next four fiscal years (Defense National Stockpile Center, 2000b).

In 2000 and early 2001, the U.S. Fish and Wildlife Service (FWS) granted final approval to two tungsten-based shot products for hunting waterfowl and coots—tungsten-matrix shot (95.9 parts tungsten to 4.1 parts polymer) and tungsten-nickel-iron shot (50% tungsten, 35% nickel, and 15% iron, by weight) (U.S. Fish and Wildlife Service, 2000, 2001). These approvals bring the number of tungtsen-based shot products approved for hunting waterfowl and coots to four. In 1999, FWS gave approval to tungsten-iron shot and tungsten-polymer shot.

The "Green Ammunition" program was part of a joint service effort chaired by the U.S. Army Armaments Research, Development and Engineering Center to eliminate the use of hazardous materials in the production of small caliber ammunition. One component of the program was to find an alternative for the lead-antimony cores in small-caliber ammunition projectiles. During the year, two candidate materials, tungsten-nylon and tungsten-tin composites, were tested to evaluate the following: their leaching characteristics in sand, soil, and water; the biological uptake of the materials by earthworms; and the recovery and recycling of tungsten and other metals following the use of bullets made from these materials (Middleton, 2000, p. 13-21).

Production

Domestic production statistics for tungsten are based on data collected by the U.S. Geological Survey (USGS) by means of two separate voluntary surveys. Statistics that result from these surveys are listed in tables 1 and 3.

The annual Tungsten Ore and Concentrate Survey covered the production, purchases, disposition, and stocks of tungsten ores and concentrates. No tungsten was mined in the United States in 2000. In early 2001, Avocet Mining plc sold the land and residual assets associated with the Pine Creek Mine in Bishop, CA (Avocet Mining plc, 2001).

The monthly Tungsten Concentrate and Tungsten Products Survey canvassed companies that produced tungsten carbide powder, tungsten chemicals, and/or tungsten metal powder from ammonium paratungstate, tungsten-bearing scrap, and tungsten concentrate. The USGS received responses from 11 of the 12 processing operations on the survey; estimates were made for the nonresponding operation.

Major U.S. processors of tungsten materials operating in 2000 included Allegheny Technologies Inc.'s Metalworking Products business, Huntsville, AL; General Electric Co., Euclid, OH; Kennametal Inc., Latrobe, PA, and Fallon, NV; OM Group, Inc. (OMG), Midland, MI, and St. George, UT; and Osram Sylvania Inc., Towanda, PA.

In 2000, U.S. processors consumed slightly less tungsten concentrate, approximately the same amount of tungsten-bearing scrap, and 20% more ammonium paratungstate than they did in 1999. Domestic production of ammonium paratungstate was higher than that of 1999. Total net production of all primary tungsten products (hydrogen-reduced metal powder, tungsten carbide powder, and tungsten chemicals) increased by 10% in 2000 compared with that of 1999.

During the year, Avocet Tungsten Inc. permanently closed its Bishop, CA, tungsten processing plant. According to the company, while the plant was competitive in some value added products such as ammonium metatungstate and pressed powders, the basic tungsten conversion business could not compete with other processing operations. Avocet Tungsten's last production of ammonium paratungstate from stockpiled ore concentrates was in March. The plant and associated equipment were sold at auction in July (Avocet Mining plc, 2000b; Ryan's Notes, 2000). With the closure of the Bishop plant, the United States had two remaining plants that processed tungsten concentrates—Kennametal's tungsten carbide plant in Fallon, NV, and Osram Sylvania's tungsten processing plant in Towanda, PA.

OMG reportedly planned to increase production of ammonium paratungstate at its processing plant in St. George, UT, late in the year. Some of the increased production was to be from reprocessing tungsten carbide powder purchased from the DNSC. The plant typically used hard and soft cemented carbide scrap as feed for its ammonium paratungstate production (Magdics, 1998, p. 22; Platt's Metals Week, 2000).

N.V. Union Minière S.A. of Brussels, Belgium, resolved the technical problems associated with the startup of its Nanodyne Inc. nanocrystalline powder plant in Laurinburg, NC. The plant was designed to have the capacity to produce 500 metric tons per year (t/yr) of composite metal powders, such as tungsten carbide-cobalt powders, by using a spray-conversion process. The Nanodyne plant is adjacent to Union Minière's Carolmet Cobalt Products plant, which produced cobalt metal powder and salts (American Metal Market, 1998; N.V. Union Minière S.A., 2001, p. 13).

In November, Praxair, Inc. and Advance Research Chemicals, Inc. announced that they had formed a strategic alliance to develop, manufacture, and market high-purity tungsten hexafluoride for the semiconductor industry. Production was to occur at a new plant in Catoosa, OK. The plant's capacity was approximately 4.5 t/yr, gross weight, of tungsten hexafluoride (Praxair, Inc., 2000).

Consumption

U.S. apparent consumption of all tungsten materials, as calculated from net imports, primary and secondary production, and changes in Government and industry stock levels, was 14,300 t in 2000, an increase of 11% from that of 1999. In 2000, a decrease in net imports was more than equaled by shipments of tungsten materials from the NDS and an increase in scrap consumption.

Statistics on consumption of tungsten in end-use applications by U.S. metal consumers were developed from the voluntary Consolidated Consumers Survey. For this survey, nearly 70 tungsten consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 4 include estimates to account for nonrespondents. Total U.S. reported consumption of tungsten materials to make end-use products increased by 5% in 2000 compared with that of 1999. The increase was the result of increased consumption by producers of mill products for lighting and other industries, superalloys, and other alloys. As compared with 1999, in 2000,

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U.S. industry consumed more tungsten metal powder and tungsten scrap, less ferrotungsten and tungsten chemicals, and approximately the same amount of tungsten carbide powder.

Weekly reports of the number of operating drilling rigs give an indication of the demand for cemented carbide components used by industry to explore for or produce oil and natural gas. During 2000, the trend in the number of rigs that operated in the United States continued the increase that began in April 1999. The lowest weekly count during 2000 was 755 in late January and the highest count was 1,114 in late December. In 2000, the average number of operating rigs in the United States increased 47% to 918, as compared with the 625 operating rigs in 1999 (Baker Hughes Inc., 2001, North American rig counts, accessed January 10, 2001, at URL http://www.bakerhughes.com/investor/rig/rig_na.htm).

In 2000, total consumption of tungsten scrap by U.S. processors and consumers was 5,120 t of contained tungsten, which was a 3% increase from the 4,980 t consumed in 1999.

Prices

Most published prices for ammonium paratungstate and tungsten concentrates significantly increased during the second half of 2000. The increase was the result of continued efforts by China, the world's largest tungsten supplier, to reform its industry (see China section of this report). Specifically, tighter control on exports of ammonium paratungstate was cited as the reason for increased prices (Metal Bulletin, 2000a, b, c). Ammonium paratungstate prices reported by Metal Bulletin began to increase in July. Metal Bulletin's annual average of high and low prices for ammonium paratungstate in the U.S. market was $66 per metric ton unit ($60 per short ton unit), 17% higher than that of 1999. Platt's Metals Week's U.S. price for ammonium paratungstate began to increase in September. Platt's annual average of high and low prices was $64 per metric ton unit ($59 per short ton unit), 13% higher than that of 1999. Annual average prices of ammonium paratungstate are listed in table 1.

The price of tungsten concentrates reported by Metal Bulletin began to increase in September. The average tungsten concentrate price reported by Metal Bulletin was $45 per metric ton unit, which was 12% higher than that of 1999. In contrast, the average of U.S. spot tungsten ore concentrate prices reported by Platt's Metals Week remained unchanged from that of 1999 at $47 per metric ton unit ($43 per short ton unit). Prices of tungsten concentrates are listed in tables 1 and 5.

Foreign Trade

The total tungsten content of U.S. exports was 2,870 t, approximately the same as the 2,880 t exported in 1999. As shown in tables 6 through 10, exports of tungsten carbide powder, tungsten ores and concentrates, tungsten wire, and other tungsten metal increased as compared with those of 1999, and exports of ammonium paratungstate, other tungstates, tungsten metal powders, tungsten waste and scrap, and wrought tungsten decreased.

The total tungsten content of U.S. imports was 8% lower than that of 1999. China, which continued to be the largest supplier of imported tungsten to the United States, provided 48% of all tungsten imports in 2000. The total tungsten content of imports from China decreased slightly in 2000 to 4,910 t, as compared with 5,000 t in 1999. Of the imports from China, 36% was ammonium paratungstate; 25%, tungsten oxides; 14%, concentrates; 8%, ferrotungsten; 5%, tungsten metal powders; 5%, tungsten waste and scrap; 3%, tungsten carbide powder; and the remainder, calcium tungstate, other tungstates, unwrought tungsten, and wrought tungsten.

Russia, which was the next largest supplier of imported tungsten materials to the United States, provided 17% of U.S. imports. In 2000, Russian imports were mainly tungsten oxide (49%), tungsten concentrates (23%), ammonium paratungstate (15%), tungsten waste and scrap (9%), ferrotungsten and tungsten metal powders (each 2%). Total imports from Russia decreased by 26% to 1,710 t of contained tungsten in 2000 compared with 2,300 t in 1999.

As shown in table 11, U.S. imports of tungsten ores and concentrates decreased by 17% in 2000 compared with those of 1999. Imports of concentrates originating from China resumed as a result of the termination of the 151% antidumping duty (see Legislation and Government Programs section of this report). In contrast, imports of ores and concentrates from Kazakhstan and Russia decreased significantly from those of 1999. In 2000, 95% of U.S. imports of ores and concentrates originated from six countries—China (29%), Portugal (21%), Bolivia (19%), Russia (17%), Peru (5%), and Rwanda (4%).

U.S. imports of ammonium paratungstate increased 18% as compared with those of 1999 (table 12). China continued to be the dominant supplier, providing 78% of U.S. ammonium paratungstate imports.

In 2000, imports of calcium tungstate, other tungsten chemicals, tungsten carbide powder, tungsten metal powders, unwrought tungsten, and wrought tungsten increased compared with those of 1999, but those of ferrotungsten, other tungstates, tungsten chlorides and tungsten waste and scrap decreased. Imports of tungsten oxides were at similar levels during the past 2 years (tables 13, 14).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States. In 2000, net import reliance as a percent of apparent consumption was 63%. Because there was no U.S. mine production in 2000, this indicates that 63% of U.S. tungsten supply was from imports and stock releases and 37% was from scrap materials generated in the United States.

World Review

As shown in table 15, estimated world production of tungsten concentrates increased 4% as compared with that of 1999. China remained the leading world producer of tungsten concentrates. In addition to mine production and tungsten recovered from scrap, tungsten materials from stockpiles in Russia and other countries in the Commonwealth of Independent States (CIS) have been a significant component of world supply in recent years. Between 1992, when exports of tungsten from CIS countries first entered western markets, and mid-2000, an estimated 41,800 t of tungsten was exported from CIS countries. Information on the amount of tungsten that remained in CIS stockpiles and whether these materials would be released for export continued to be unavailable. During the past few years, however, the quantity of tungsten exported from the CIS has been decreasing (Kerr, 2001, p. 18-19; Maby, 2000,

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p. 3-6; Martin, 2000; Trickett, 2000).

Austria.—Wolfram Bergbau und Hutten GmbH Nfg KG produced tungsten concentrates from the Mittersill scheelite mine in the Province of Salzburg. All these concentrates were converted to primary tungsten products at Wolfram Bergbau's Bergla tungsten processing plant in the Province of Steiermark.

Canada.—North American Tungsten Corp. Ltd. commissioned a mining and geological engineering firm to prepare a report on the company's tungsten assets and to review internal reports to evaluate the economic potential of restarting production from the company's CanTung Mine in southwestern Northwest Territories, near the border with Yukon Territory. On the basis of the firm's report, North American Tungsten felt that production from the CanTung Mine would provide the company with an attractive internal rate of return at current (September 2000) prices for tungsten concentrates. As a result of these findings, North American Tungsten and its marketing advisors began discussions with major consumers of tungsten concentrates for the purpose of entering into long-term supply contracts and with investment bankers (North American Tungsten Corp. Ltd., 2001c, d).

China.—The Chinese Government continued to reorganize its nonferrous metals industry. In July, the Government decided to dissolve the centrally controlled holding company China Rare Metals and Rare Earth Group Corp. (CRRC) and to transfer the management of its mines, plants, and research institutes to local governments. Management of the tungsten mines formerly controlled by Tungsten Mining Corp., which was a subgroup of CRRC, was transferred to Jiangxi, Hunan, and Guangdong Provinces. The assets and equity of China Tungsten & Cemented Carbide Industry Corp. (CTCCC), another subgroup of CRRC, and China Tungsten & Advanced Materials Corp., which was CTCCC's holding company, were transferred to the provinces of Hunan, Sichuan, and Hainan, where the assets were located. CTCCC consisted of Zhuzhou Cemented Carbide Works, Zigong Cemented Carbide Co., and Jinhai Industry Co. China Tungsten & Advanced Materials Corp. was a listed company on the domestic stock exchange formed by combining partial assets from Zhuzhou and Zigong (Juqiu, 2000).

After the transfer of the tungsten enterprises, the Chinese Government planned to continue to take action to make full use of its tungsten resources. The Government planned to continue to control the export of tungsten materials from China by imposing quotas on products such as ammonium paratungstate, tungsten concentrates, and tungsten oxides; by encouraging the export of value-added downstream tungsten products; and by giving priority to key enterprises of metallurgy, processing, and trade when granting export licenses. The Government planned to continue to control total tungsten production by closing mines that were running out of resources; by banning mines operating without licenses; by ordering tungsten metallurgical facilities that used outdated processes, that wasted resources, or that caused environmental pollution to make improvements or cease operating; and by allowing plants with poor management and debts surpassing their assets to go bankrupt. The Government would no longer directly control the enterprises. Rather, it planned to focus on formulating laws, regulations, and industrial policy; on giving guidance on production and marketing; on establishing an orderly market; and on promoting the sustained development of the Chinese tungsten industry. The China Non-Ferrous Metals Industry Association was established to take on some responsibilities for administration, to participate in developing regulations and standards for the industry, and to coordinate relationships between industries and between Government and individual enterprises (Juqiu, 2000).

Czech Republic.—Hydrometalurgicke Zavody, a.s. (HMZ) produced tungsten metal powders, tungsten carbide powders, cobalt sulfate, and other chemical products at its plant in Bruntál. The plant used ammonium paratungstate and sintered cemented carbide scrap as feed. In August, Osram GmbH of Munich, Germany, announced that it had signed a letter of intent to purchase HMZ (Šarman, 1999; Osram Sylvania Inc., 2000).

Portugal.—Beralt Tin & Wolfram S.A., an Avocet subsidiary, expanded production from the Panasqueira Mine (Avocet Mining plc, 2000a).

Russia.—According to the State Statistics Committee, Russian production of metallic tungsten in 2000 was 90% of that of 1999 (Interfax International Ltd., 2001).

During the year, efforts were underway to rehabilitate the Orlovsky GOK tungsten concentrator in Chita oblast in eastern Siberia. Recommissioning of the concentrator, which had been idle since 1994, was to occur in March or April 2001. Production of tungsten concentrates at full capacity levels was not anticipated to occur before 2002. The plant was to process locally mined ores (Interfax International Ltd., 2000).

Vietnam.—Tiberon Minerals Ltd. of Calgary, Alberta, Canada, explored the Nui Phao exploration license area 80 kilometers north of Hanoi. In September, the company began a drilling program to test tungsten-gold-copper-bismuth-tin mineralization in the Da Lien prospect. Initial results from one drill core showed tungsten grades similar to those at deposits currently being mined in China, Austria, and elsewhere. The company planned to expand its exploration activities to three additional mineralized targets within the license area (Tiberon Minerals Ltd., 2000).

Outlook

Demand for tungsten tends to follow general economic conditions. Future consumption of tungsten in cemented carbides, which is the largest end-use sector, will depend on the performance of the following industries: automotive and aircraft production, construction, mining, oil and gas drilling, and semiconductor and other manufacturing. Some recent developments in uses for tungsten include the shift from lead to tungsten for military and recreational ammunition and the use of tungsten by the sporting goods industry to make golf clubs and golf ball cores. The consumption of tungsten to produce 5.56 millimeter "green ammunition" for the military was forecast to grow from nearly zero in 2000 to between 450 t and 800 t of tungsten in 2005 (Middleton, 2000, p. 22).

World tungsten supply will continue to be dominated by Chinese production and exports. Beginning in 1999, the Chinese Government took several steps to control the release of tungsten to the market, which resulted in significant increases in the prices of ammonium paratungstate and tungsten concentrates during the latter half of 2000. Higher prices are expected to encourage an increase in the production of tungsten concentrates outside China. For example, in Bolivia, Empresa Minera Urania S.A. began to increase production in 2001 and planned to reopen two closed mines; International Mining Co. planned to increase tungsten production from its La Chojlla tungsten-tin operation; and Empresa Minera Himalaya Ltda. entered into an agreement with North American Tungsten to study the feasibility of developing a tungsten-tin deposit in

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Murillo and Sadyumyai Provinces. In Canada, North American Tungsten continued to advance its plans to reopen the Cantung Mine and in 2001 signed a concentrate sales and loan agreement with Osram Sylvania and Sandvik AB (Metal Bulletin, 2001; North American Tungsten Corp. Ltd., 2001a, b).

References Cited

American Metal Market, 1998, New Nanodyne plant to produce smallest tungsten grain: American Metal Market, v. 106, no. 165, August 27, p. 5.

Avocet Mining plc, 2000a, Interim results for the six months ended 30 September 2000: London, Avocet Mining plc press release, December 14, 3 p.

———2000b, Preliminary audited results for the year ending 31 March 2000: London, Avocet Mining plc press release, July 13, 4 p.

———2001, Penjom gold production, tungsten update and Bishop sale: London, Avocet Mining plc press release, April 26, 2 p.

Defense National Stockpile Center, 2000a, Annual Materials Plan for FY 2001: Fort Belvoir, VA, Defense National Stockpile Center news release, September 26, 2 p.

———2000b, Stockpile issues tungsten ores and concentrates solicitation: Fort Belvoir, VA, Defense National Stockpile Center news release, December 7, 1 p.

Interfax International Ltd., 2000, New rare metals plant may be commissioned in spring 2001: Mining & Metals Report, v. 9, issue 39 (444), September 22-28, p. 14.

———2001, Russian nonferrous production up 11.3%: Mining & Metals Report, v. 10, issue 6 (462), February 2-8, p. 30.

International Trade Administration, 1999, August 1999 Sunset reviews—Termination of review, final results of reviews and revocation and termination: Federal Register, v. 64, no. 212, November 3, p. 59737-59738.

Juqiu, Zhou, 2000, Re-organization of China's non-ferrous metals industry, *in* Annual General Meeting, 13th, Washington, DC, September 27-28, 2000, Transcripts of Papers: London, International Tungsten Industry Association, 4 p.

Kerr, A.J., 2001, Ferro tungsten—China holds the key, *in* Metal Bulletin's Ferro-Alloys Conference, 3d, Kowloon, Hong Kong, March 26, 2001, Proceedings: London, Metal Bulletin, 27 p.

Maby, Michael, 2000, Market report by the Secretary-General, *in* Annual General Meeting, 13th, Washington, DC, September 27-28, 2000, Transcripts of Papers: London, International Tungsten Industry Association, 12 p.

Magdics, Alex, 1998, Recycling cobalt and nickel battery waste at OMG, *in* International seminar on battery waste management, 10th, Deerfield Beach, FL, October 26-28, 1998, Proceedings: Boca Raton, Florida Educational Seminars, Inc., 33 p.

Martin, R.T., 2000, Tungsten, *in* Ryan's Notes Annual Ferroalloys Conference, Boca Raton, FL, October 30-31, 2000, Proceedings: Pelham, NY, Ryan's Notes, 6 p.

Metal Bulletin, 2000a, Chinese export cuts see APT price surge: Metal Bulletin, no. 8505, September 4, p. 8.

———2000b, Export cuts force China to postpone APT shipments: Metal Bulletin, no. 8511, September 25, p. 10.

———2000c, Minmetals confirms antimony export cuts and industry shake-up: Metal Bulletin, no. 8491, July 10, p. 9.

———2001, Bolivian tungsten producers seek output increases: Metal Bulletin, no. 8569, April 26, p. 7.

Middleton, J.R., 2000, Overview—Elimination of toxic/hazardous materials from small caliber ammunition, *in* Annual General Meeting, 13th, Washington, DC, September 27-28, 2000, Transcripts of Papers: London, International Tungsten Industry Association, 26 p.

North American Tungsten Corp. Ltd., 2001a, Company looks to add to it's [sic] tungsten assets—North American Tungsten acquires Bolivian interests: Vancouver, British Columbia, North American Tungsten Corp. Ltd. news release, March 1, 3 p.

———2001b, Company signs concentrate sales and loan agreement with its strategic alliance partners: Vancouver, British Columbia, North American Tungsten Corp. Ltd. news release, May 22, 1 p.

———2001c, Quarterly and year end report—For the quarter ended September 30, 2000: Vancouver, British Columbia, North American Tungsten Corp. Ltd., February 16, 4 p.

———2001d, Tungsten prices continue to strengthen: Vancouver, British Columbia, North American Tungsten Corp. Ltd. news release, January 8, 1 p.

N.V. Union Minière S.A., 2001, Materials for a better life—Review of 2000 Operations: Brussels, N.V. Union Minière S.A., 44 p.

Osram Sylvania Inc., 2000, Summary—Osram Sylvania's parent company, Osram GmbH, signs letter of intent to purchase HMZ: Danvers, MA, Osram Sylvania Inc. press release, August 18, 1 p.

Platt's Metals Week, 2000, OMG bosting [sic] APT output: Platt's Metals Week, v. 71, no. 40, October 2, p. 12-13.

Praxair, Inc., 2000, Praxair and Advance Research Chemicals form alliance to manufacture tungsten hexafluoride: Danbury, CT, Praxair, Inc. press release, November 3, 2 p.

Ryan's Notes, 2000, Assets at sole US tungsten mine liquidated: Ryan's Notes, v. 6, no. 30, July 24, p. 2-3.

Šarman, Luděk,1999, HMZ, a.s.—Recycling process of hardmetal scrap—History and present time, *in* Tungsten—Advanced technology & new applications: International Tungsten Symposium, 8th, Fukuoka, Japan, October 12-15, 1999, Transcripts of Papers, London, 3 p.

Tiberon Minerals Ltd., 2000, Tiberon updates exploration program: Calgary, Alberta, Canada, Tiberon Minerals Ltd. news release, December 4, 2 p.

Trickett, Alex, 2000, Tungsten market hangs in the balance: Metal Bulletin Monthly, no. 356, August, p. 40-43.

U.S. Department of Defense, 2001, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 1999 through September 2000: U.S. Department of Defense, 54 p.

U.S. Fish and Wildlife Service, 2000, Migratory bird hunting; Approval of tungsten-matrix shot as nontoxic for hunting waterfowl and coots—Final rule: Federal Register, v. 65, no. 173, September 6, p. 53936-53940.

———2001, Migratory bird hunting; Approval of tungsten-nickel-iron shot as nontoxic for hunting waterfowl and coots—Final rule: Federal Register, v. 66, no. 3, January 4, p. 737-742.

U.S. International Trade Commission, 1999, Tungsten ore concentrates from China and uranium from Kyrgyzstan: Federal Register, v. 64, no. 219, November 15, p. 61939.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Recycling—Metals. Ch. in Minerals Yearbook, annual.
Tungsten. Ch. in Metal Prices in the United States through 1998, 1999.
Tungsten. Ch. in Mineral Commodity Summaries, annual.
Tungsten. Ch. in Minerals Yearbook, annual.
Tungsten. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Tungsten. International Strategic Mineral Issues Summary Report, Circular 930-O, 1998.
Tungsten. Mineral Industry Surveys, monthly.

Other

American Metal Market, daily.
Company annual reports and press releases.
Defense Logistics Agency, Defense National Stockpile Center.
Engineering & Mining Journal, monthly.
Federal Register, daily.
Interfax International Ltd., Mining & Metals Report, weekly.
International Tungsten Industry Association [United Kingdom].
Materials flow of tungsten in the United States, U.S. Bureau of Mines Information Circular 9388, 1994.
Metal Bulletin [London], semiweekly and monthly.
Mining Journal [London], weekly, Metals & Minerals Annual Review, Mining Annual Review.
Platt's Metals Week, weekly.
Roskill Information Services Ltd. [London].
Ryan's Notes, weekly.
Strategic and Critical Materials Report to the Congress, Department of Defense.
The tungsten industry of the U.S.S.R., U.S. Bureau of Mines Mineral Issues, 1988.
Tungsten. Ch. in Mineral facts and problems. U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT TUNGSTEN STATISTICS 1/

(Metric tons, tungsten content, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Concentrates:					
Consumption	5,260	6,590	3,210 2/	2,100 2/	W
Exports	18	12	10	26	70
Imports for consumption	4,190	4,850	4,750	2,870	2,370
Stocks, December 31:					
Consumer	569	658	514	W	W
U.S. Government 3/	34,600	34,600	34,600	34,600	33,400
Price, per metric ton unit:					
U.S. spot quotation 4/	$66	$64	$52	$47	$47
European 5/	$53	$47	$44	$40	$45
Ammonium paratungstate:					
Production	4,450 6/	5,380 6/	838 7/	7,050 r/	W
Consumption	7,790	9,300	10,000	7,490	8,980
Stocks, December 31, producer and consumer	558	W	603	376	W
Price, per metric ton unit:					
U.S. free market 8/	$83	$77	$66	$56	$66
U.S. market 4/	$96	$83	$65	$57	$64
Primary products:					
Net production 9/	7,810	8,300	9,630	8,500	9,470
Consumption 10/	8,170 r/	8,830 r/	9,550 r/	8,760 r/	9,180
Stocks, December 31:					
Producer 11/	1,400	1,210	1,340	1,070	1,160
Consumer 10/	413	610	524	534 r/	504
U.S. Government 3/	2,700	2,700	2,700	2,700	2,110
World production of concentrate	34,700 r/	33,200	37,400 r/	36,100 r/	37,400 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to no more than three significant digits.

2/ Excludes 6 months of "Withheld" data.

3/ Defense National Stockpile Center. Includes material committed for sale pending shipment.

4/ Annual average calculated from weekly prices reported by Platt's Metals Week.

5/ Annual average calculated from semiweekly prices reported by Metal Bulletin.

6/ Excludes 4 months of "Withheld" data.

7/ Excludes 11 months of "Withheld" data.

8/ Annual average calculated from annual average high and low prices reported by Metal Bulletin.

9/ Includes only tungsten metal powder and tungsten carbide powder made from metal powder.

10/ Includes scrap.

11/ Data for 1996-98 exclude cast and crystalline tungsten carbide powder. Data for 1999-2000 exclude cast and crystalline tungsten carbide powder and chemicals.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE TUNGSTEN STATISTICS IN 2000 1/ 2/

(Metric tons, tungsten content)

	Inventory, yearend 3/		Annual materials	Sales		Inventory decrease 4/	
Material	Fiscal year 5/	Calendar year	plan, fiscal year 5/	Fiscal year 5/	Calendar year	Fiscal year 5/	Calendar year
Ores and concentrates	33,500	33,400	1,810	1,360	1,360	1,100	1,240
Ferrotungsten	815	775	136	142	597	103	143
Tungsten metal powder	757	757	68	67	71	104	104
Tungsten carbide powder	680	577	454	749	576	242	345
Total	35,800	35,500	2,470	2,320	2,610	1,550	1,830

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes stockpile- and nonstockpile-grade materials.

3/ Includes material committed for sale pending shipment.

4/ From previous year.

5/ Twelve-month period ending September 30, 2000.

Source: Defense National Stockpile Center.

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TABLE 3
U.S. NET PRODUCTION AND STOCKS OF TUNGSTEN PRODUCTS 1/ 2/

(Metric tons, tungsten content)

	Hydrogen reduced metal powder	Tungsten carbide powder		Chemicals	Total
		Made from metal powder	Cast and crystalline		
Net production:					
1999	4,540	3,960	W	W	8,500
2000	4,980	4,490	W	W	9,470
Producer stocks:					
December 31, 1999	626	441	W	W	1,070
December 31, 2000	621	538	W	W	1,160

W Withheld to avoid disclosing company proprietary data.
1/ Net production equals gross production less quantity used to make other products in table.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
U.S. REPORTED CONSUMPTION AND STOCKS OF TUNGSTEN PRODUCTS 1/ 2/ 3/

(Metric tons, tungsten content)

	1999	2000
Consumption by end use:		
Steels	486	408
Superalloys	306	403
Other alloys 4/	W	W
Cemented carbides 5/	5,910	5,960
Mill products made from metal powder	W	W
Chemical uses	93	89
Total	8,760 r/	9,180
Consumption by form:		
Ferrotungsten	484	388
Tungsten metal powder	1,860 r/	2,270
Tungsten carbide powder	5,930	5,980
Tungsten scrap	356	459
Other tungsten materials 6/	125	89
Total	8,760 r/	9,180
Consumer stocks, December 31:		
Ferrotungsten	33	33
Tungsten metal powder	15	29
Tungsten carbide powder	445 r/	381
Tungsten scrap	23	44
Other tungsten materials 6/	19	17
Total	534 r/	504

r/ Revised. W Withheld to avoid disclosing company proprietary data, included in "Total."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Does not include materials used in making primary tungsten products.
3/ Includes estimates.
4/ Includes welding and hard-facing rods and materials, wear- and corrosion-resistant alloys, and nonferrous alloys.
5/ Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.
6/ Includes tungsten chemicals.

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TABLE 5
MONTHLY PRICE QUOTATIONS OF TUNGSTEN CONCENTRATES IN 2000

	Metal Bulletin (London), European market, 65% WO_3 basis, c.i.f. 1/				Platt's Metals Week, U.S. spot quotations, 65% WO_3 basis, c.i.f. U.S. ports, including duty 2/			
	Dollars per metric ton unit			Dollars per short ton unit,	Dollars per short ton unit			Dollars per metric ton unit,
Month	Low	High	Average	average	Low	High	Average	average
January	38	48	43	39	40	45	43	47
February	38	48	43	39	40	45	43	47
March	38	48	43	39	40	45	43	47
April	40	48	44	40	40	45	43	47
May	40	48	44	40	40	45	43	47
June	40	48	44	40	40	45	43	47
July	36	48	42	38	40	45	43	47
August	34	48	41	37	40	45	43	47
September	36	50	43	39	40	45	43	47
October	40	53	47	42	40	45	43	47
November	42	55	49	44	40	45	43	47
December	50	55	53	48	40	45	43	47

1/ Combined wolframite and scheelite quotations. Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average annual price per metric ton unit of WO_3 of all semiweekly low and high prices was $45 in 2000. The average equivalent price per short ton unit of WO_3 was $41 in 2000.
2/ Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average annual price per short ton unit of WO_3 of all weekly low and high prices was $43 in 2000. The average equivalent price per metric ton unit of WO_3 was $47 in 2000.

TABLE 6
U.S. EXPORTS OF TUNGSTEN ORES AND CONCENTRATES, BY COUNTRY 1/

	1999			2000		
Country of destination	Gross weight (metric tons)	Tungsten content 2/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content 2/ (metric tons)	Value (thousands)
Afghanistan	(3/)	(3/)	4	--	--	--
Argentina	--	--	--	(3/)	(3/)	3
Brazil	1	(3/)	9	--	--	--
China	--	--	--	5	2	71
Ecuador	1	(3/)	11	--	--	--
France	--	--	--	1	1	23
Germany	2	1	23	(3/)	(3/)	3
Hungary	--	--	--	1	1	20
Ireland	5	3	83	--	--	--
Italy	--	--	--	2	1	31
Japan	1	(3/)	17	10	5	148
Korea, Republic of	1	1	20	15	8	190
Luxembourg	--	--	--	1	1	13
Mexico	(3/)	(3/)	4	--	--	--
Netherlands	27	14	462	54	28	832
Russia	--	--	--	16	8	250
Singapore	(3/)	(3/)	6	--	--	--
Slovakia	--	--	--	(3/)	(3/)	4
South Africa	--	--	--	(3/)	(3/)	9
Sweden	--	--	--	(3/)	(3/)	7
Taiwan	--	--	--	1	(3/)	10
Thailand	1	1	21	--	--	--
United Kingdom	11	6	166	28	15	439
Total	51	26	826	135	70	2,050

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Content estimated from reported gross weight.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 7
U.S. EXPORTS OF AMMONIUM PARATUNGSTATE, BY COUNTRY 1/

Country of destination	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Belgium	79	$673	2	$17
Czech Republic	--	--	25	204
Denmark	7	71	14	143
France	--	--	1	13
Germany	9	80	10	87
Japan	6	56	--	--
Korea, Republic of	(2/)	4	--	--
Mexico	(2/)	23	(2/)	4
Singapore	--	--	1	4
Spain	(2/)	4	1	17
Total	103	911	53	489

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
U.S. EXPORTS OF TUNGSTEN METAL POWDERS, BY COUNTRY 1/ 2/

Country of destination	1999 Gross weight (metric tons)	1999 Tungsten content 3/ (metric tons)	1999 Value (thousands)	2000 Gross weight (metric tons)	2000 Tungsten content 3/ (metric tons)	2000 Value (thousands)
Australia	12	9	$163	5	4	$162
Austria	2	2	50	(4/)	(4/)	26
Belgium	45	36	392	--	--	--
Brazil	7	6	212	16	13	428
Canada	57	46	1,500	66	53	1,880
Chile	4	3	161	1	1	34
China	(4/)	(4/)	19	2	2	85
Congo (Kinshasa)	10	8	51	--	--	--
Egypt	--	--	--	8	6	124
France	31	25	673	8	6	523
Germany	236	188	6,570	264	212	7,780
Hong Kong	19	15	29	4	3	133
India	90	72	1,570	1	(4/)	35
Israel	41	33	494	11	9	128
Italy	21	17	813	13	10	582
Japan	48	38	624	26	21	776
Korea, Republic of	8	6	132	2	2	119
Mexico	34	27	338	8	7	138
Netherlands	25	20	733	15	12	135
Panama	2	1	33	--	--	--
Poland	3	2	100	--	--	--
Saudi Arabia	--	--	--	6	4	$72
Singapore	6	5	$325	4	3	249
South Africa	4	3	61	2	1	69
Spain	1	1	60	2	2	101
Sweden	76	61	395	25	20	206
Switzerland	30	24	947	1	1	43
Taiwan	22	17	587	28	22	747
Turkey	(4/)	(4/)	20	4	3	74
United Kingdom	51	41	1,810	60	48	2,220
Other	4 r/	4	137 r/	3	3	155
Total	889	711	19,000	583	467	17,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ May include tungsten alloy powders.
3/ Content estimated from reported gross weight.
4/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF TUNGSTEN CARBIDE POWDER, BY COUNTRY 1/

Country of destination	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Argentina	2	$12	--	--
Australia	7	182	6	$158
Austria	20	362	6	61
Belgium	20	413	3	94
Brazil	6	195	2	106
Canada	177	4,490	181	4,460
China	--	--	3	50
Czech Republic	5	65	--	--
France	25	241	10	196
Germany	163	4,800	162	3,370
Hong Kong	11	165	(2/)	3
India	5	107	2	41
Ireland	8	282	1	117
Israel	26	313	16	193
Italy	62	1,630	64	1,650
Japan	15	808	13	686
Korea, Republic of	6	228	3	99
Luxembourg	13	158	--	--
Malaysia	(2/)	22	3	127
Mexico	3	61	12	294
Netherlands	53	736	11	314
Singapore	1	91	1	143
South Africa	21	314	18	254
Sweden	20	287	137	1,950
Switzerland	2	122	(2/)	7
Taiwan	(2/)	19	5	118
United Kingdom	27	622	306	4,370
Venezuela	1	53	2	66
Other	2	81 r/	2	80
Total	701	16,900	969	19,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 10
U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of destination	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Ferrotungsten and ferrosilicon tungsten:				
Canada	2	$26	(2/)	$6
Japan	--	--	3	44
Mexico	2	20	1	12
Total	4	46	4	62
Unwrought tungsten and waste and scrap: 3/ 4/ 5/				
Australia	22	143	4	30
Belgium	76	436	44	181
Brazil	1	11	1	7
Canada	5	77	48	338
China	2	7	58	329
France	1	10	3	47
Germany	226	1,230	395	1,640
Hong Kong	6	35	2	10
India	72	1,160	--	--
Israel	29	151	21	128
Italy	20	122	17	98
Japan	24	136	15	87

See footnotes at end of table.

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TABLE 10--Continued
U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of destination	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Unwrought tungsten and waste and scrap--Continued: 3/ 4/ 5/				
Korea, Republic of	12	71	12	71
Malaysia	9	60	3	21
Mexico	42	252	10	99
Netherlands	27	168	32	180
Norway	--	--	2	13
Philippines	14	80	20	112
Portugal	4	23	--	--
Singapore	1	6	20	127
Sweden	4	23	6	33
Taiwan	58	464	82	598
United Kingdom	186	1,140	26	148
Other	2	24 r/	6	59
Total	843	5,820	827	4,350
Wrought tungsten--wire: 3/ 4/				
Belgium	1	131	12	573
Brazil	11	695	10	647
Canada	10	458	11	481
China	3	290	1	200
France	9	924	16	939
Germany	1	179	7	710
Hong Kong	5	72	2	48
Hungary	16	868	24	1,750
India	22	1,400	15	912
Indonesia	2	117	10	476
Italy	2	249	9	465
Japan	14	935	17	1,920
Korea, Republic of	1	103	1	80
Mexico	9	888	27	2,170
Netherlands	3	105	3	165
Philippines	1	29	1	41
Singapore	1	159	1	196
Spain	6	386	15	1,420
Sweden	2	201	2	109
United Kingdom	3	1,160	2	318
Other	2 r/	296 r/	1	428
Total	122	9,650	187	14,000
Wrought tungsten, excluding wire: 3/ 4/				
Brazil	17	$483	(2/)	$18
Canada	19	810	22	954
China	(2/)	104	1	49
France	1	145	2	237
Germany	205	4,400	158	3,220
India	22	505	4	232
Israel	1	134	(2/)	41
Italy	1	84	2	155
Japan	14	1,290	6	818
Korea, Republic of	(2/)	27	1	89
Malaysia	1	25	--	--
Mexico	4	295	5	545
Netherlands	1	23	(2/)	3
Qatar	--	--	1	15
Poland	1	28	--	--
Singapore	(2/)	108	(2/)	124
Spain	--	--	2	176
Sweden	(2/)	43	1	114
Taiwan	1	119	(2/)	25
United Kingdom	6	376	3	250
Venezuela	1	21	(2/)	6
Other	2	192 r/	1	216
Total	297	9,210	210	7,290

See footnotes at end of table.

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TABLE 10--Continued
U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of destination	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Other tungsten metal: 3/ 4/				
Australia	6	527	2	318
Brazil	1	130	1	116
Canada	10	634	15	857
Finland	1	95	(2/)	25
France	1	162	2	358
Germany	2	520	6	1,020
Hungary	(2/)	65	3	245
India	1	52	(2/)	23
Israel	5	1,100	1	353
Japan	5	1,940	6	1,890
Korea, Republic of	2	167	(2/)	71
Mexico	8	846	8	807
Netherlands	1	88	1	221
Singapore	1	431	3	639
Taiwan	3	487	3	654
Turkey	1	34	--	--
United Kingdom	7	977	12	1,250
Other	3	626 r/	5	780
Total	57	8,880	68	9,630
Tungsten compounds: 6/				
Belgium	16	291	--	--
Canada	1	3	13	31
Mexico	--	--	(2/)	14
United Kingdom	1	23	--	--
Total	18	317	13	45

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ May include alloys.
4/ Content estimated from reported gross weight.
5/ Includes bars and rods obtained by sintering.
6/ Includes only other tungstates.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF TUNGSTEN ORES AND CONCENTRATES, BY COUNTRY 1/

Country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Australia	167	$601	--	--
Bolivia	361	1,670	449	$2,310
Burma	91	283	--	--
China	--	--	699	3,470
Kazakhstan	461	1,610	31	119
Mexico	27	75	--	--
Mongolia	55	138	67	261
Peru	22	136	107	460
Portugal	353	1,960	499	2,770
Russia	1,200	5,440	395	1,350
Rwanda	55	154	100	300
Thailand	11	45	12	49
Uganda	--	--	12	59
United Kingdom	72	274	--	--
Total	2,870	12,400	2,370	11,100

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PARATUNGSTATE, BY COUNTRY 1/

Country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Austria	--	--	18	$126
China	1,760	$9,070	1,760	10,200
Germany	103	968	131	844
Hong Kong	--	--	95	644
Netherlands	17	77	--	--
Russia	--	--	265	1,600
Sweden	34	115	--	--
Total	1,920	10,200	2,270	13,400

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF FERROTUNGSTEN AND FERROSILICON TUNGSTEN, BY COUNTRY 1/

Country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
China	498	$2,930	395	$2,160
Germany	3	38	--	--
Russia	168	793	30	182
United Kingdom	--	--	45	255
Total	669	3,760	470	2,600

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Tungsten metal powders: 2/				
Belgium	3	$122	3	$138
Canada	4	117	6	53
China	145	2,000	267	2,790
Germany	32	865	70	1,580
Israel	7	125	50	584
Japan	15	1,400	17	1,340
Korea, Republic of	(3/)	8	8	133
Russia	3	24	26	213
South Africa	(3/)	2	--	--
United Kingdom	100	927	138	1,330
Other	-- r/	-- r/	8	39
Total	310	5,590	593	8,190
Tungsten carbide powder:				
Austria	43	639	16	431
Canada	412	6,590	540	8,180
China	113	1,740	167	2,200
France	(3/)	23	5	333
Germany	79	1,680	123	2,390
Hong Kong	--	--	8	102
Israel	77	1,700	86	1,300
Japan	2	77	7	471
Korea, Republic of	10	44	13	194
Luxembourg	34	577	13	252
Netherlands	--	--	8	124
Russia	20	78	11	126

See footnotes at end of table.

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TABLE 14--Continued
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Tungsten carbide powder--Continued:				
United Kingdom	(3/)	7	1	42
Other	1	93	2	148
Total	790	13,200	1,000	16,300
Unwrought tungsten: 2/ 4/ 5/				
Austria	2	170	7	109
Canada	3	11	21	33
Germany	2	234	2	135
United Kingdom	(3/)	12	2	148
Other	(3/)	20	1	27
Total	8	447	32	452
Waste and scrap:				
Austria	17	147	11	89
Bermuda	12	65	--	--
Canada	19	102	24	109
China	169	1,380	253	2,200
Estonia	--	--	19	122
France	--	--	3	12
Germany	151	779	79	404
Hong Kong	13	120	--	--
India	16	64	9	41
Indonesia	13	101	--	--
Ireland	13	114	25	115
Israel	21	71	9	97
Japan	314	1,530	64	310
Korea, Republic of	60	212	146	420
Mexico	--	--	2	11
Netherlands	13	110	35	179
Russia	343	1,810	151	995
Singapore	11	59	9	49
South Africa	72	462	60	322
Sweden	11	66	--	--
Ukraine	16	$154	--	--
United Kingdom	93	545	30	$179
Uzbekistan	59	437	55	497
Other	2	12	8	72
Total	1,440	8,340	993	6,230
Wrought tungsten wire, plate, sheet, strip, foil, other: 2/ 4/				
Austria	17	2,490	39	4,490
Belgium	(3/)	9	1	113
Canada	21	649	(3/)	31
China	24	1,330	59	3,030
Estonia	(3/)	3	8	77
France	2	302	5	586
Germany	78	6,270	92	5,880
Hong Kong	1	37	1	89
Hungary	11	809	6	483
India	(3/)	30	1	52
Israel	11	1,010	13	968
Italy	(3/)	5	1	76
Japan	28	5,600	22	7,600
Korea, Republic of	(3/)	50	2	203
Mexico	1	601	(3/)	220
Netherlands	1	245	1	249
Russia	15	121	(3/)	12
Singapore	(3/)	78	1	95
Switzerland	3	416	3	433
United Kingdom	3	518	4	525
Other	(3/) r/	57 r/	1	408
Total	217	20,600	260	25,600
Tungsten oxides:				
Australia	--	--	36	188
China	1,530	7,940	1,220	6,730

See footnotes at end of table.

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TABLE 14--Continued
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country of origin	1999 Tungsten content (metric tons)	1999 Value (thousands)	2000 Tungsten content (metric tons)	2000 Value (thousands)
Tungsten oxides--Continued:				
Germany	1	28	(3/)	9
Netherlands	19	102	--	--
Russia	555	2,350	836	4,900
United Kingdom	4	29	--	--
Other	(3/)	5	--	--
Total	2,110	10,500	2,090	11,800
Calcium tungstate:				
China	--	--	97	317
Japan	1	24	(3/)	9
Total	1	24	97	326
Other tungstates:				
China	763	3,240	2	12
Germany	8	143	(3/)	30
Total	770	3,380	2	42
Other tungsten compounds: 6/				
Belgium	--	--	(3/)	2
France	(3/)	3	--	--
Germany	1	143	(3/)	34
Ireland	--	--	(3/)	4
Japan	2	513	1	159
Netherlands	--	--	1	7
Total	3	659	3	205

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ May include alloys.
3/ Less than 1/2 unit.
4/ Content estimated from reported gross weight.
5/ Includes bars and rods obtained by sintering; excludes powders and waste and scrap.
6/ Includes tungsten chlorides.

Source: U.S. Census Bureau.

TABLE 15
TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, tungsten content)

Country	1996	1997	1998	1999	2000
Austria	1,413	1,400 e/	1,423	1,610	1,600 e/
Bolivia	582	513	497	334	381
Brazil	99	40	--	13 r/	14
Burma 3/	334	272	178	87	82 e/
Burundi e/	16	16	10	10	10
China e/	26,500	25,000	30,000 r/	29,000 r/	30,000
India	2	1	--	--	--
Korea, North e/	900	900	800	700	700
Mexico	188	179	130	40 r/	--
Mongolia e/	17	26	35	16	15 e/
Peru	332	280	76	--	--
Portugal	776	1,036	831	434 r/	750
Russia e/	3,000	3,000	3,000	3,500	3,500
Rwanda	49 r/	33 r/	149 r/	97 r/	130
Tajikistan e/	50	--	--	--	--
Thailand e/	37	30	35	30 r/	30
Uzbekistan e/	300	250	200	200	200
Vietnam	130	210	--	--	--
Total	34,700 r/	33,200	37,400 r/	36,100 r/	37,400

e/ Estimated. r/ Revised. -- Zero.
1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Tungsten concentrates are believed to be produced in Kyrgyzstan, but information is inadequate for making production estimates. Table includes data available through May 30, 2001.
3/ Includes content of tin-tungsten concentrate.

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VANADIUM

By Robert G. Reese, Jr.

Domestic survey data and tables were prepared by Adam A. Wario, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2000, all U.S. vanadium production was from various industrial waste streams. Fewer than 10 firms, primarily in Arkansas, Louisiana, Texas, and Utah, processed materials such as vanadium-bearing iron slag, fly ash, petroleum residues, and spent catalysts to produce vanadium pentoxide, ferrovanadium, and vanadium metal. Recycling of vanadium was negligible; only small quantities of vanadium-based catalysts and vanadium-aluminum alloy were recycled.

Vanadium consumption in the United States decreased for the third consecutive year. Metallurgical applications in which vanadium was used as a minor alloying element with iron, steel, and titanium remained the dominant use and accounted for more than 90% of domestic consumption. The largest nonmetallurgical use for vanadium was in catalysts.

Six countries recovered vanadium from ores, concentrates, slag, or petroleum residues (table 7). China, Russia, and South Africa were the leading nations in vanadium production. In four of the five foreign countries, vanadium production was primarily a byproduct of iron mining and processing.

The U.S. Geological Survey (USGS) estimates that the vanadium reserve base is more than 27 million metric tons, a sufficiently large supply that by itself can satisfy the market for several hundred years at the present rate of consumption. Additionally, the expected increase recovery of vanadium from spent catalyst, fly ash, and petroleum residues will extend the viability of the reserve base significantly.

Legislation and Government Programs

The U.S. Department of Commerce (DOC) conducted an expedited review of the antidumping duties on Russian ferrovanadium and nitrided vanadium. The DOC found that the antidumping duties should be maintained. The duties ranged from 3.75% to 108%, depending on the producing company (Ryan's Notes, 2000a).

The U.S. International Trade Commission decided in September to conduct a full review of the antidumping duties on Russian ferrovanadium and nitrided vanadium (Ryan's Notes, 2000b). A ruling was expected in 2001.

Production

Near midyear, CS Metals of Louisiana LLP commissioned a new plant in Convent, LA (Metals Week, 2000). The plant will process spent petroleum catalysts and at full capacity is expected to recover nearly 2,300 metric tons (t) per year of vanadium pentoxide, molybdenum oxide, and possibly some nickel.

Consumption

In 2000, domestic vanadium consumption was 3,520 t. Although vanadium has many uses, metallurgical applications account for essentially all domestic consumption. Most vanadium is consumed in the form of ferrovanadium, which is used as a means of introducing vanadium into steels where it gives additional strength and toughness. Ferrovanadium is available as alloys containing 45% to 50% and 80% vanadium. The 45% to 50% grade is produced from slag and other vanadium-containing materials by the silicothermic reduction of vanadium pentoxide. Most of the 80% grade is produced by the aluminothermic reduction of vanadium pentoxide in the presence of steel scrap or by direct reduction in an electric arc furnace. Vanadium steels can be subdivided into microalloyed

Vanadium in the 20th Century

Metallurgical research near the end of the 19th century had shown the benefits of adding vanadium to tool steels and machinery for added toughness and fatigue resistance. However, vanadium was not an important commercial metal in the early 20th century because it was relatively rare and therefore expensive as well as difficult to produce in a pure form. In 1901, the United States produced approximately 340 metric tons of ore containing uranium and vanadium primarily from mining operations in Colorado. The first commercial production of ferrovanadium occurred domestically in 1907.

The commercial importance of vanadium was established during the first third of the century. Discovery of high-grade deposits in Namibia, Peru, and Zambia, along with additional development of the deposits on the Colorado Plateau in the Western United States, did much to ensure a sufficient supply of vanadium. Metallurgical progress was also being made during this period in the production of ferrovanadium. Simultaneously, commercial uses for vanadium-containing steels, such as in automobiles and armor plating, were being developed. Among the nonmetallurgical applications developed during this period was the use of vanadium pentoxide as a catalyst in the production of sulfuric acid. This type of catalyst was introduced into the United States in 1926 and gradually replaced platinum.

Vanadium uses changed little during the century. In 2000, metallurgical uses still dominated, accounting for more than 90% of domestic vanadium consumption. The source of vanadium supplies, however, changed significantly. Rather than recovering vanadium from ores as was done during the first half of the century, such materials as vanadium-bearing iron slag, fly ash, petroleum residues, and spent catalysts were processed to produce vanadium pentoxide, ferrovanadium, and vanadium metal.

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or low-alloy steels, which generally contain less than 0.15% vanadium, and high-alloy steels, which contain as much as 5% vanadium. Nonmetallurgical applications include catalysts (which is the dominant use), ceramics, vanadium chemicals, and electronics.

The USGS derived vanadium consumption data from a voluntary survey of domestic consuming companies. For this survey, more than 80 vanadium companies were canvassed on a monthly or annual basis. Consumption data reported in tables 1 and 2 contain estimates for nonrespondents.

Prices

In 2000, the domestic price for ferrovanadium, as published in Metal Bulletin, ranged from $3.85 to $6.60 per pound, a wider range than the $4.35 to $6.25 range reported for 1999. The price reached its high in March and declined steadily throughout the remainder of the year. The lowest price was reported in December. The European ferrovanadium price recorded its high for the year in March and its low in January. The European price ranged from $7.45 to $13.50 per kilogram compared with $7.45 to $13.70 in 1999.

Metal Bulletin's published price for domestic vanadium pentoxide ranged between $1.25 and $2.65 per pound in 2000. The price peaked in March and steadily declined throughout the year. In 1999, Metal Bulletin's vanadium pentoxide price ranged from $1.25 to $2.90 per pound.

World Review

Nearly all the world's supply of vanadium is from primary sources. Six countries recovered vanadium from ores, concentrates, slag, or petroleum residues (table 7). The largest vanadium-producing nations remained China, Russia, and South Africa, with production primarily a byproduct of iron mining and processing. Japan and the United States were believed to be the only countries to recover significant quantities of vanadium from petroleum residues.

Recycling of vanadium was negligible. Its major use was as a minor element in iron, steel, and titanium-bearing alloys from which it is not extracted when those metals are recycled. Only small quantities of vanadium-based catalysts and vanadium-aluminum alloy were processed to recover vanadium.

In October, Precious Metal Australia Ltd. sold its 40% interest in the Windimurram vanadium mine to its joint venture partner Xstrata AG (American Metal Market, 2000). Precious Metal Australia retained a 15% net profit interest in the mine.

Outlook

In the near term, the major factor affecting the vanadium market will be the demand for steel. Longer term however, the consumption of vanadium will probably increase owing, in part, to the need for stronger and lighter steels and, in part, to the demand created by new applications, such as the vanadium battery. As in the United States, worldwide demand for vanadium is expected to be closely and directly related to the demand for steel.

References Cited

American Metal Market, 2000, Xstrata raises vanadium stake: American Metal Market, v. 108, no. 201, October 18, p. 16.
Metals Week, 2000, New US vanadium/moly recycling plant commissioned: Metals Week, v. 71, no. 27, July 3, p. 11.
Ryan's Notes, 2000a, Commerce keeps duty on Russian FeV: Ryan's Notes, v. 6, no. 42, October 16, p. 3.
———2000b, The U.S. International Trade Commission: Ryan's Notes, v. 6, no. 38, September 18, p. 3.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Vanadium. Ch. in Mineral Commodity Summaries, annual.
Vanadium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Vanadium. International Strategic Minerals Inventory Summary Report, Circular 930-K, 1992.
Vanadium. Mineral Industry Surveys, monthly.

Other

Chemical and Engineering News.
Engineering and Mining Journal.
Metal Bulletin.
Metal Bulletin Monthly [London].
Metalworking News.
Roskill Reports [London].

TABLE 1
SALIENT VANADIUM STATISTICS 1/

(Metric tons of contained vanadium, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium 2/	W	W	W	W	W
Value thousand dollars	W	W	W	W	--
Vanadium oxide recovered from ore 3/	W	W	W	W	--
Vanadium receovered from petroleum residues 4/	3,730	NA	NA	NA	NA
Consumption	4,630	4,710	4,380	3,620 r/	3,520
Exports:					
Ferrovanadium	479	446	579	213	172
Vanadium pentoxide (anhydride)	241	614	681	747	653
Other oxides and hydroxides of vanadium	2,670	385	232	70	100

See footnotes at end of table.

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TABLE 1--Continued
SALIENT VANADIUM STATISTICS 1/

(Metric tons of contained vanadium, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Imports for consumption:					
Ferrovanadium	1,880	1,840	1,620	1,930	2,510
Vanadium pentoxide (anhydride)	485	711	847	208	902
Other oxides and hydroxides of vanadium	11	126	33	--	14
Ore, slag, ash, residues	2,270	2,950	2,400	1,650	1,890
Stocks:					
Ferrovanadium	294	311	324	328 r/	257
Oxide	7	8	8	5 r/	5
Other 5/	4	4	4	15 r/	20
World, production from ore, concentrate, slag 6/	40,900	40,700	44,500	43,600 r/	43,000

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ Data are rounded to no more than three significant digits.
2/ Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mill, plus vanadium recovered from ferrophosphorus slag derived from domestic phosphate rock.
3/ Produced directly from all domestic ores and ferrophosphorus slag; includes metavanadates.
4/ Includes vanadium recovered from fly ash, petroleum residues, and spent catalysts.
5/ Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanada
6/ Excludes U.S. production.

TABLE 2
U.S. CONSUMPTION OF VANADIUM, BY END USE AND FORM 1/

(Kilograms of contained vanadium)

	1999	2000
End use:		
Steel:		
Carbon	1,050,000 r/	1,190,000
Stainless and heat resisting	W	W
Full alloy	861,000 r/	685,000
High-strength low-alloy	865,000 r/	931,000
Tool	W	225,000
Total	2,770,000 r/	3,030,000
Cast irons	W	W
Superalloys	13,500	17,000
Alloys (excluding steels and superalloys):		
Welding and alloy hard-facing rods and materials	W	W
Other alloys 2/	402,000	392,000
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	433,000 r/	79,100
Total	3,620,000 r/	3,520,000
Form:		
Ferrovanadium	2,920,000 r/	2,920,000
Oxide	296,000 r/	189,000
Other 3/	409,000 r/	411,000
Total	3,620,000 r/	3,520,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneou and unspecified."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes magnetic alloys.
3/ Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

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TABLE 3
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY AND VANADIUM METAL, INCLUDING WASTE AND SCRAP 1/

(Kilograms, gross weight)

	Aluminum-vanadium master alloy		Vanadium metal, including waste and scrap	
	Quantity	Value	Quantity	Value
Imports for consumption:				
1999	1,210,000	$1,680,000	30,400	$779,000
2000:				
Belgium	10,300	55,800	--	--
Germany	--	--	35,900	488,000
Netherlands	6,040	24,600	--	--
Russia	47	2,850	8830	438000
Taiwan	--	--	33	9,790
United Kingdom	--	--	1	2,940
Total	16,400	83,200	44,800	939,000
Exports:				
1999	514,000	6,440,000	177,000	3,200,000
2000:				
Australia	1010	13100	439	43,100
Belgium	--	--	464	10,500
Brazil	4250	125000	--	--
Canada	359,000	4,660,000	4,930	110,000
China	19,900	267,000	--	--
France	446	7600	9,840	109,000
Germany	--	--	33	28,700
Ireland	227	2,950	--	--
Israel	53,500	718,000	--	--
Italy	615	8,000	5	4990
Japan	43,200	670,000	1,110	25,000
Korea, Republic of	19,100	213,000	--	--
Malaysia	2,400	24,500	--	--
Mexico	166,000	2,250,000	--	--
El Salvador	424	12,500	--	--
South Africa	582	20,100	--	--
Spain	595	19,900		
Switzerland	--	--	1	7,790
Taiwan	577	7500	--	--
United Kingdom	4910	94400	88400	1340000
Venezuela	--	--	59	4010
Total	677,000	9,120,000	105,000	1,680,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE), AND OTHER OXIDES AND HYDROXIDES OF VANADIUM 1/

(Kilograms, contained vanadium)

	Ferrovanadium		Vanadium pentoxide (anhydride) 2/		Other oxides and hydroxides of vanadium	
	Quantity	Value	Quantity	Value	Quantity	Value
Imports for consumption:						
1999	1,930,000	$20,700,000	208,000	$1,920,000	--	--
2000:						
Austria	289,000	3,000,000	--	--	--	--
Belgium	117,000	1,290,000	--	--	--	--
Canada	316,000	3,100,000	--	--	--	--
China	666,000	5,870,000	--	--	--	--
Czech Republic	537,000	5,480,000	--	--	--	--
Germany	4,020	35,100	2,350	29,400	--	--
Hong Kong	15,900	148,000	--	--	--	--

See footnotes at end of table.

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TABLE 4--Continued
U.S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE), AND OTHER OXIDES AND HYDROXIDES OF VANADIUM 1/

(Kilograms, contained vanadium)

	Ferrovanadium		Vanadium pentoxide (anhydride) 2/		Other oxides and hydroxides of vanadium	
	Quantity	Value	Quantity	Value	Quantity	Value
Imports for consumption--Continued:						
2000--Continued:						
Japan	3,990	43,400	1,400	33,200	--	--
Luxembourg	--	--	--	--	50	$3,000
Mexico	15,200	160,000	--	--	--	--
Netherlands	--	--	4,850	22,900	--	--
Niger	48,300	400,000	--	--	--	--
South Africa	480,000	5,230,000	894,000	6,170,000	--	--
Taiwan	12,600	136,000	--	--	--	--
United Kingdom	--	--	--	--	13,500	228,000
Total	2,510,000	24,900,000	902,000	6,260,000	13,500	231,000
Exports:						
1999	213,000	3,180,000	747,000	4,270,000	69,700	656,000
2000:						
Belgium	--	--	195,000	881,000	2,430	21,600
Brazil	--	--	800	6,600	6,210	32,500
Canada	133,000	1,760,000	--	--	22,700	248,000
Chile	--	--	274,000	1,280,000	--	--
France	--	--	181	3,980	--	--
Germany	--	--	18,100	93,200	16,600	145,000
Hong Kong	285	9,470	--	--	--	--
India	--	--	--	--	6,800	66,200
Italy	--	--	36,000	188,000	1,200	4,000
Japan	170	16,500	2,830	26,800	--	--
Korea, Republic of	--	--	49,400	469,000	--	--
Kuwait	--	--	--	--	430	3,820
Mexico	36,300	512,000	--	--	39,800	176,000
Panama	--	--	--	--	411	5,840
Peru	--	--	4,870	20,600	--	--
Russia	2,030	67,500	56,000	268,000	--	--
Saudi Arabia	--	--	4,560	45,600	--	--
Spain	--	--	9,000	49,000	--	--
Switzerland	--	--	18	3,010	--	--
Taiwan	--	--	--	--	532	4,730
Thailand	--	--	--	--	2,710	33,100
Venezuela	--	--	2,190	20,800	--	--
Total	172,000	2,360,000	653,000	3,360,000	99,800	741,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ May include catalysts containing vanadium pentoxide.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES, AND SLAG 1/

(Kilograms, vanadium pentoxide content)

Material and country	1999		2000	
	Quantity	Value	Quantity	Value
Ash and residues:				
Canada	146,000	$101,000	91,600	$80,500
Hungary	44,700	44,500	--	--
Italy	519,000	319,000	807,000	584,000
Mexico	856,000	5,740,000	1,100,000	869,000
Netherlands Antilles	13,200	9,890	--	--
United Kingdom	224,000	722,000	421,000	673,000
Total	1,800,000	6,940,000	2,420,000	2,210,000
Slag, from the manufacture of iron and steel, South Africa 2/	1,150,000	1,740,000	959,000	1,650,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES, AND SLAG 1/

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ As adjusted by the U.S. Geological Survey.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS 1/ 2/

(Kilograms, vanadium content)

Material and country	1999		2000	
	Quantity	Value	Quantity	Value
Sulfates:				
India	8	$14,300	475	$4,570
China	--	--	397	26,500
Total	8	14,300	872	31,000
Vanadates:				
Germany	77,700	724,000	47,600	328,000
Japan	24	79,500	78	165,000
South Africa	96,400	837,000	89,900	500,000
Switzerland	--	--	1	5,170
Taiwan	--	--	10,700	38,000
Total	174,000	1,640,000	148,000	1,040,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Comprises vanadium ore and miscellaneous vanadium chemicals.

Source: U.S. Census Bureau.

TABLE 7
VANADIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained vanadium)

Country	1996	1997	1998	1999	2000 e/
Production from ores, concentrates, slag: 3/					
China (in vanadiferous slag product) e/	14,000	15,000	15,500	16,000	16,000
Hungary e/	200	200	100	--	--
Kazakhstan e/	900	900	1,000	1,000	1,000
Russia e/	11,000	9,000	9,000	9,000	9,000
South Africa	14,770	15,590	18,868	17,612 r/	17,000
United States (recoverable vanadium)	W	W	W	W	--
Total	40,900	40,700	44,500	43,600 r/	43,000
Production from petroleum residues, ash spent catalysts: 4/					
Japan e/	245	245	245	245	245
United States	3,730	NA	NA	NA	NA
Total	3,980	NA	NA	NA	NA
Grand total	44,800	NA	NA	NA	NA

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ In addition to the countries listed, vanadium is also recovered from petroleum residues in Germany and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through June 7, 2001.
3/ Production in this section is credited to the country that was the origin of the vanadiferous raw material.
4/ Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.

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VERMICULITE

By Michael J. Potter

Domestic survey data and tables were prepared by Nicholas Muniz, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Vermiculite is a hydrated magnesium-aluminum-iron silicate. Flakes of raw vermiculite concentrate are mica-like in appearance and contain water molecules within their internal structure. When the flakes are heated rapidly at a temperature of 900° C or higher, the water flashes into steam, and the flakes expand into accordion-like particles. The color, which can range from black and various shades of brown to yellow for the raw flakes, changes to gold or bronze. This expansion process is also called exfoliation, and the resulting lightweight material is chemically inert, fire resistant, and odorless. In lightweight plaster and concrete, vermiculite provides good thermal insulation. Vermiculite can absorb such liquids as fertilizers, herbicides, and insecticides, which can then be transported as free-flowing solids (Harben and Kuzvart, 1996).

Production

Domestic production (sold or used) data for vermiculite were collected by the U.S. Geological Survey (USGS) from two voluntary surveys—one for mine/mill operations and the other for exfoliation plants. Of three mine/mill operations, data were obtained from one. Output for the two nonrespondents was estimated based on previous years' production levels and estimates

Because there have only been three U.S. mining operations (two companies) of vermiculite concentrate in recent years, vermiculite data collected by the USGS are proprietary and must be withheld. However, according to Moeller (2001, p. 65), estimated U.S. output in 2000 was about 150,000 metric tons (t) (table 1). The two U.S. producers of vermiculite concentrate were W.R. Grace & Co., from its operation at Enoree, SC; and Virginia Vermiculite Ltd., with operations near Woodruff, SC, and in Louisa County, VA.

Vermiculite concentrate was shipped to exfoliating plants for conversion into lightweight material. Output of exfoliated vermiculite sold or used in 2000, using partly estimated data, was about 165,000 t (table 1). Domestic production of exfoliated vermiculite sold or used was by 13 companies operating 19 plants in 10 States (table 2). Of the 19 known exfoliation plants, 9, or 47%, responded. The nine operations produced 42% of the sold or used vermiculite listed in tables 1 and 3. Data for the remaining operations were estimated from previous years' production levels. States that produced exfoliated vermiculite, in descending order of output sold and used, were South Carolina, Ohio, Arizona, Pennsylvania, New Jersey, Arkansas, Florida, Illinois, Texas, and New Mexico.

Stansbury Holdings Corp. faced some unanticipated circumstances at its vermiculite operation at Dillon, MT. These included forest fires, the onset of a harsh winter, and mechanical breakdowns at its vermiculite mill. Also, the company's Los Banos, CA, exfoliating plant was facing new, more restrictive State air emissions standards. Consideration was being given to locating the Los Banos plant to another California location or to Nevada or Montana (Stansbury Holdings Corp., May 15, 2001, Letter to shareholders, accessed June 27, 2001, at URL http://www.stansburyholdings.com/shareholder_letters/may2000. html).

Consumption

Horticultural and other related applications, such as soil conditioning and free-flowing fertilizer carrier medium, continued to be major end uses of vermiculite. In soil conditioning, vermiculite particles retain moisture and nutrients, releasing them gradually to plant roots. The air spaces improve aeration of soil and create passageways for drainage (GTG Hydroponics, [undated], Soils and soil amendments, accessed August 21, 2001, at URL http://www.gtghydroponics.com/soil.htm). One supplier was offering, for example, a number of horticultural mixes that varied in composition but fell within the composition range of 10% to 55% Canadian sphagnum peat moss, 10% to 65% vermiculite, 5% to 20% perlite, 0% to 25% oak bark, and 0% to 60% pine bark. Uses for these products included seed starting, cutting propagation, and provision for

Vermiculite in the 20th Century

Vermiculite in the United States was first produced in small quantities in the mid-1920s. By 1936, the first year that vermiculite output was recorded by the U.S. Bureau of Mines, production of vermiculite concentrate had reached about 15,400 metric tons. The major use for exfoliated (expanded) vermiculite was for heat, cold, or sound insulation. It was used loose as a filler in the walls of houses and in water heaters, fire safes, stoves, furnaces, and refrigerators. It also served as a lightweight aggregate in insulating plaster, concrete, and other materials, where insulating and sound-deadening properties and low specific gravity were of value. Output of vermiculite concentrate in the United States reached a high of about 331,000 tons in 1973.

In 2000, U.S. output of vermiculite concentrate was an estimated 150,000 tons. Insulation and agricultural uses (such as horticulture and soil conditioning) accounted for about 80% of the usage of the exfoliated vermiculite product. U.S. imports of vermiculite were about 59,000 tons; South Africa supplied about 74%, and China, about 23%. South Africa had the world's largest output of vermiculite during the 1990s, and in 2000, it produced about 209,000 tons.

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aeration, percolation, and nutrient retention characteristics in horticulture and some landscape applications (The Scotts Company, Summer 2001, Product guide—Soil mixes & amendments, accessed July 31, 2001, at URL http://www.scotts.com/professionalhoriculture/SoilMixesAmendments.cfm).

Another application of vermiculite was use beneath above-ground swimming pools as a pool cushion. It provides a soft, level surface that protects the vinyl liner from sharp objects. Vermiculite also can be mixed with portland cement to form an insulating monolithic porous concrete base for use beneath vinyl inground swimming pools. The base protects pools from being damaged by changes in the water table and hydrostatic pressure (The Schundler Co., [1994]).

Prices

Published prices for vermiculite serve as a general guide only because of variations in source, quantity, application, and other factors. Prices for raw (unexpanded) U.S. vermiculite concentrate, bulk, ex-plant were about $143 to $220 per metric ton, depending on particle size. For imported South African crude vermiculite, bulk, f.o.b. barge, U.S. Gulf Coast, prices ranged from $187 to $243 per ton (Industrial Minerals, 2000b).

The average value of U.S. exfoliated vermiculite sold or used by producers, using partly estimated data, was $322 per metric ton (table 1) and was a composite value including both U.S. and imported material.

Foreign Trade

Trade data for vermiculite concentrate are not collected as a separate category by the U.S. Census Bureau but are included within the basket category "vermiculite, perlite, and chlorite, unexpanded" under tariff code 2530.10.0000. According to Moeller (2001), U.S. exports of vermiculite concentrate in 2000 were about 5,000 t (table 1) and were believed to be shipped primarily to Canada. Total U.S. imports of vermiculite in 2000 were about 59,000 t (Port Import/Export Reporting Service, data printout, 2001). South Africa supplied about 74% of the tonnage, and China, 23%.

World Review

In Western Europe, the United Kingdom was the major consumer of vermiculite. The largest end use in Western Europe was for building boards, which were essentially of two types. One type was produced using a wet slurry manufacturing process; the other type was made using a binder such as metal silicate or equivalent (Ellicott, 2000).

A number of companies in Western Europe produced exfoliated vermiculite for the horticultural market. The insulation market included loose-fill insulation and insulation shapes for uses that included secondary insulation in such industrial installations as aluminum smelters (Ellicott, 2000).

Canada.—Normiska Corp., Mississauga, Ontario, signed an agreement to acquire VIL Vermiculite, Inc., for about $1.8 million. VIL's assets included manufacturing facilities for horticultural grades of vermiculite and perlite in Lachine, Quebec. Normiska's product lines included sphagnum peat moss, pine bark mulches, and composts (Industrial Specialties News, 2000).

South Africa.—Palabora Mining Co. Ltd. is the world's largest supplier and exporter of vermiculite from its operation in the northern Transvaal. Material is exported worldwide (Russell, 2000). The company formerly named Natkruit Vermiculite Mine (Pty.) Ltd., which is located north of Pietersburg, was purchased by an offshore holding company and became known as Natkruit Mine. Plans called for an increase in output to 24,000 metric tons per year (t/yr) by 2001 from 18,000 t/yr. Natkruit was exporting vermiculite largely to the refractory, horticultural, and fire protection industries of Europe (Industrial Minerals, 2000a).

Outlook

Although horticultural and related applications have been the largest end uses of vermiculite in the United States in recent years, other uses appear to be growing, including as an intumescent (swelling) material for use, for example, in gaskets. Another use is in coatings and binders (chemically delaminated vermiculites that form high-tensile-strength films). As finely ground material, vermiculite serves as a functional filler in coatings, construction materials, and friction brake applications (Moeller, 2001). Materials that compete with vermiculite in general include mineral wool, perlite, and polystyrene (Ellicott, 2000).

Although South Africa is the largest supplier of vermiculite, Australia, Brazil, China, and Zimbabwe have significant output. Production of the mineral in China was said to be increasing, and that country may become a major supplier in the future (Moeller, 2001).

References Cited

Ellicott, Graham, 2000, Crude vermiculite—Producers & refined markets: Industrial Minerals, no. 391, April, p. 21-27.

Harben, P.W., and Kuzvart, Milos, 1996, Vermiculite, *in* Global geology: London, Industrial Minerals Information Ltd., p. 432-437.

Industrial Minerals, 2000a, Natkruit's new owners to expand vermiculite: Industrial Minerals, no. 393, June, p. 17.

———2000b, Prices: Industrial Minerals, no. 399, December, p. 74-75.

Industrial Specialties News, 2000, Normiska to buy VIL Vermiculite: Industrial Specialties News, v. 14, no. 1, January 10, p. 3.

Moeller, E.M., 2001, Vermiculite: Mining Engineering, v. 53, no. 6, June, p. 65.

Russell, Alison, 2000, Vermiculite: Mining Journal, Mining Annual Review 2000 Supplement, CD-ROM, 3 p.

The Schundler Co., [1994], Swimming pool vermiculite: Metuchen, NJ, The Schundler Co. product information sheet, 1 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Vermiculite. Ch. in Mineral Commodity Summaries, annual.

Lightweight Aggregates. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Vermiculite. Ch. in Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, 6th ed., Donald Carr, ed., 1994.

Vermiculite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

The Vermiculite Association (www.vermiculite.org), Lincoln, United Kingdom.

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TABLE 1
SALIENT VERMICULITE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1996	1997	1998	1999	2000
United States:					
Sold and used by producers:					
Concentrate	W	W	W	175 e/	150 e/
Exfoliated	135	155 e/	170 e/	175 e/	165 e/
Value	$45,300	$49,400 e/	$53,300 e/	$55,300 e/	$53,200 e/
Average value 2/	$334	$318 e/	$313 e/	$315 e/	$322 e/
Exports e/	8	9	11	13	5
Imports for consumption	48	67	68	71	59
World, production 3/	280 4/	301 4/	328 r/ 4/	541 r/	512 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to no more than three significant digits.

2/ Based on unrounded data.

3/ Excludes production by countries for which data were not available.

4/ Excludes U.S. data.

TABLE 2
ACTIVE VERMICULITE EXFOLIATION PLANTS IN THE UNITED STATES IN 2000

Company	County	State
J.P. Austin Associates, Inc.	Beaver	Pennsylvania.
P.V.P. Industries	Trumbull	Ohio.
Palmetto Vermiculite Co., Inc.	Spartanburg	South Carolina.
The Schundler Co.	Middlesex	New Jersey.
The Scotts Company	Hempstead	Arkansas.
Do.	Union	Ohio.
Do.	Greenville	South Carolina.
Southwest Vermiculite Co., Inc.	Bernalillo	New Mexico.
Sun Gro Horticulture, Inc.	Jefferson	Arkansas.
Do.	La Salle	Illinois.
Thermic Refractories, Inc.	Macoupin	Do.
Thermo-O-Rock, Inc.	Maricopa	Arizona.
Do.	Washington	Pennsylvania.
Verlite Co.	Hillsborough	Florida.
Vermiculite Industrial Corp.	Allegheny	Pennsylvania.
Vermiculite Products, Inc.	Harris	Texas.
W.R. Grace & Co., Construction Products Division	Maricopa	Arizona.
Do.	Broward	Florida.
Do.	Greenville	South Carolina.

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TABLE 3
ESTIMATED EXFOLIATED VERMICULITE
SOLD AND USED IN THE UNITED STATES, BY END USE 1/

(Metric tons, unless otherwise specified)

	1999	2000
Aggregates 2/	28,300	25,000
Insulation 3/	W	W
Agricultural:		
Horticultural	27,200	33,800
Soil conditioning	39,600	31,300
Fertilizer carrier	W	W
Total	W	W
Other 4/	6,290	W
Grand total	175,000	165,000

W Withheld to avoid disclosing company proprietary data; included in "Grand total."
1/ Data rounded to no more than three significant digits; may not add to totals shown.
2/ Includes acoustic insulation, fireproofing, and texturizing uses.
3/ Includes high-temperature and packing insulation and sealants.
4/ Includes various industrial and other uses not specified.

TABLE 4
VERMICULITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Argentina e/	40	822 3/	1,000 r/	2,800 r/	2,800
Australia e/	2,500	5,000	10,000	12,000	12,000
Brazil	21,999	23,000	24,300	23,400 r/	23,000
China	NA	NA	NA	40,000 e/	40,000
Egypt	447	447	12,376	12,000 e/	12,000
India	2,405	4,405	4,080	4,000 e/	4,200
Japan e/	15,000	15,000	15,000	15,000	15,000
Kenya	734	1,418	353	164 r/	165
Mexico	350	295	--	100 e/	100
Russia e/	30,000	25,000	25,000	25,000	25,000
South Africa	196,000	211,001	221,300	217,800 r/	208,835 3/
United States, sold and used by producers 4/	W	W	W	175,000 e/	150,000
Zimbabwe	10,249	14,841	14,804	13,898 r/	18,935 3/
Total	280,000	301,000	328,000 r/	541,000 r/	512,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes production by countries for which data are not available and for which general information is inadequate for formulation of reliable estimates. Table includes data available through July 20, 2001.
3/ Reported figure.
4/ Concentrate.

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WOLLASTONITE

By Robert L. Virta

Domestic survey data were prepared by Raymond I. Eldridge III, statistical assistant.

Wollastonite, a calcium metasilicate ($CaSiO_3$), has a theoretical composition of 48.3% calcium oxide and 51.7% silicon dioxide but may contain trace to minor amounts of aluminum, iron, magnesium, manganese, potassium, and sodium. It occurs as prismatic crystals that break into massive-to-acicular fragments. It is usually white, but also may be gray, brown, or red depending on its composition.

Wollastonite forms when impure limestones are metamorphosed (subjected to heat and pressure) or silica-bearing fluids are introduced into calcareous sediments during metamorphic processes. In both cases, calcite reacts with silica to produce wollastonite and carbon dioxide. Wollastonite also can crystallize directly from a magma that has an unusually high carbon content, but this is a more rare occurrence.

Deposits of wollastonite have been found in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah. These deposits also may contain calcite, diopside, garnet, idocrase, and quartz as minor components.

Wollastonite is used primarily in ceramics, friction products (brakes and clutches), metallurgy, paint, and plastics. Some of the properties that make it so useful are its high brightness and whiteness, low moisture and oil absorption, low volatile content, and the acicular nature of some wollastonite.

Production

Wollastonite has been mined commercially in California and New York. The California deposits, which are in Inyo, Kern, and Riverside Counties, were mined between 1930 and 1970. These operations were limited in size, producing only a few thousand metric tons per year for ceramics, decorative stone, paint, and mineral wool production.

Wollastonite deposits in New York have been mined for more than 50 years. Two companies currently are mining wollastonite: NYCO Minerals Inc., a subsidiary of Fording Inc., operates a mine in Essex County, and R.T. Vanderbilt Co. Inc. operates a mine in Lewis County. The NYCO Minerals deposit contains wollastonite, garnet, and diopside. Parts of the deposit are composed of up to 60% wollastonite. The ore is processed at the Willsboro plant where the garnet is removed by using high-intensity magnetic separators. NYCO also chemically modifies the surfaces of some of its wollastonite products to improve their performance. The R.T. Vanderbilt deposit in Lewis County consists primarily of wollastonite, minor amounts of calcite and prehnite, and trace amounts of diopside. The ore is processed at its Balmat plant where it is milled and air classified.

Domestic wollastonite production decreased from that of 1999. Much of the decrease occurred because NYCO Minerals began supplying powder-grade wollastonite to some of its North American customers from its operation in Sonora, Mexico, instead of its New York operation. This change permitted the company's New York operation to effectively increase its capacity for its higher value products and made better use of the company's ore reserves. Additionally, NYCO Minerals added a stirred-media grinding mill and new magnetic separators to its Willsboro plant and began pilot studies for pelletizing wollastonite fines (Fording Inc., 2000, p. 26-28). Although data collected by the U.S. Geological Survey are withheld to avoid revealing proprietary information, U.S. production was estimated to be on the order of 130,000 metric tons per year (t/yr) (Rieger, 2000).

Consumption

The use of wollastonite in the United States declined slightly from that of 1999. Sales probably were slightly lower for ceramic, metallurgy, and paint applications. Plastics markets,

Wollastonite in the 20th Century

Domestic mining of wollastonite has had a rather short history compared to many other mineral commodities. There was essentially no commercial mining of wollastonite in 1900. Small scale mining did not begin until the 1930s, and annual production was only on the order of a few thousand tons. Weathered wollastonite that looks like petrified wood was a popular product for landscaping. Wollastonite also was sold to the ceramics, mineral wool, and paint industries in small quantities. This level of production continued through the 1950s with all domestic production occurring in California. In the 1950s, a large wollastonite deposit was developed in New York, and large-scale production of wollastonite began in the United States. The high demand for housing following World War II resulted in the expansion of construction-related markets and provided a ready outlet for the increased production capacities. By 1960, U.S. wollastonite production and sales were about 35,000 metric tons; ceramics and paints were the major markets.

In 2000, production was estimated to be about 130,000 tons. Between 1960 and 1990, production and sales of wollastonite increased steadily as ceramic and paint markets expanded. Wollastonite sales also received a boost when the debate over the health risks posed by asbestos intensified during the 1970s and early 1980s. It was during this time that asbestos substitute markets, for which wollastonite was well suited, opened up. By 1990, production was estimated to be about 110,000 tons. In 2000, plastics comprised an estimated 37% of wollastonite sales, followed by ceramics (28%), metallurgical applications (10%), paint (10%), friction products (9%), and other applications (6%). Some other applications for wollastonite were abrasive wheel bond, adhesives, joint compounds, refractories, rubber filler, and welding rods. Wollastonite has been used as an asbestos substitute in such products as floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products.

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however, appear to have remained strong.

Major domestic uses of wollastonite were in plastics (37%), ceramics (28%), metallurgy (10%), paint (10%), friction products (9%), and miscellaneous (6%) (Industrial Minerals, 1999). Wollastonite also was used in adhesives, joint compounds, refractories, rubber, and wallboard applications.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing, increases green and fired strength, permits fast firing, and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding and to protect the surface of the molten metal during the continuous casting of steel. As a filler in paint, it reinforces the paint film, acts as a pH buffer, improves its resistance to weathering, reduces pigment consumption, and acts as a flatting and suspending agent. In plastics, it improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between the wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, inert, stable at high temperatures, and a good reinforcer.

Prices

Prices per metric ton for domestically produced acicular wollastonite, ex-works, were $209 for 200 mesh, $258 for 325 mesh, and $284 for 400 mesh. The price per ton, ex-works, for acicular, high-aspect-ratio wollastonite was $351 and for ground (10-micrometer) wollastonite was $694. Prices per ton for wollastonite, free on board, in bulk, were $209 for 200 mesh and $253 for 325 mesh (Industrial Minerals, 2000). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between the seller and the buyer.

Foreign Trade

Foreign trade data were not available from the U.S. Census Bureau for wollastonite. Imports previously were estimated to be between 2,500 metric tons (t) and 5,000 t. The revised estimate is between 10,000 t and 12,000 t, mainly because NYCO Minerals began supplying some of its North American customers from its operation in Mexico. Imports from China also were believed to have increased in 2000 compared with those of 1999. Most of the imports are thought to be lower-value wollastonite grades. Some wollastonite also was imported from Finland and India. Exports were estimated to be between 5,000 t and 8,000 t in 2000.

World Review

Worldwide production of wollastonite was estimated to be between 500,000 t and 550,000 t in 2000. China again was an unknown factor with regard to wollastonite production and sales. Production estimates for China typically have been in the 200,000-t/yr to 300,000-t/yr range. One source estimated exports from China to be between 100,000 t/yr and 150,000 t/yr and domestic consumption to be 100,000 t/yr, placing production in the 200,000-t/yr to 250,000-t/yr range (Roskill Information Services Ltd., 1996, p. 18). Production for Finland, India, and Mexico was estimated to be 20,000 t, 100,000 t, and 75,000 t, respectively. With the closure of the only Canadian producer, production from Canada was estimated to be at most a few hundred tons. Small tonnages probably also were produced in Chile (reported as 270 t in 1996), Namibia (reported as 347 t in 1999), North Korea, Pakistan, South Africa (reported as 200 t in 1999), and Turkey.

Canada.—The board of directors of Orleans Resources Inc. suspended production at the Lac St.-Jean plant in July 2000. A build-up of inventory, the company's financial situation, and lack of a partner prompted the action. The company planned to meet client needs from inventory (Orleans Resources Inc., 2000). Orleans Resources also hired the consulting firm KPMG International to locate a business partner for Orleans or conduct a sale of the company's assets (North American Minerals News, 2000).

Outlook

The decline of the U.S. economy, which began in 2000, probably will continue to hamper sales in the United States, causing a stagnation or slight decline in sales and consumption. Markets most likely to be affected will be in ceramics, metallurgy, and paint. Sales for friction products also may decline slightly. Decreases such as these would be expected during an economic slowdown with associated downturns in housing starts (ceramic and paint markets), automobile sales (friction products), and steel output (metallurgical applications). The most promising market is plastics; sales should increase in the coming years. Despite economic slowdowns faced by some other countries, worldwide sales of wollastonite should increase slightly as more durable goods are required for growing populations.

References Cited

Fording Inc., 2000, Annual report: Calgary, Canada, Fording Inc., 86 p.

Industrial Minerals, 1999, Wollastonite: Industrial Minerals, no. 379, April, p. 19.

———2000, Prices: Industrial Minerals, no. 399, December, p. 75.

North American Minerals News, 2000, Orleans hires KPMG: North American Minerals News, no. 65, October, p. 3.

Orleans Resources Inc., 2000, Orleans Resources suspends production activities at its Lac St-Jean wollastonite plant: Montreal, Orleans Resources Inc. press release, July 31, 1 p.

Rieger, K.C., 2000, Wollastonite: Ceramic Bulletin, v. 79, no. 8, August, p. 81-83.

Roskill Information Services Ltd., 1996, The economics of wollastonite, 6th ed.: Roskill Information Services Ltd., London, 131 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Pigments and Fillers. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Wollastonite—A versatile industrial mineral. Fact Sheet FS-002-01, 2001.

Other

Andrews, P.R.A., 1993, Wollastonite: Energy, Mines and Resources Canada Summary Report No. 18, 26 p.

American Ceramic Society.

Ceramic Industry (monthly).

Chemical Market Reporter (weekly).

Mining Engineering (monthly).

Mining Journal (monthly).

Minerals Pricewatch (monthly).

Paint and Coatings Industry (monthly).

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ZEOLITES

By Robert L. Virta

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant.

Zeolites are hydrated aluminosilicates of the alkaline and alkaline-earth metals. About 40 natural zeolites have been identified during the past 200 years; the most common are analcime, chabazite, clinoptilolite, erionite, ferrierite, heulandite, laumontite, mordenite, and phillipsite. More than 150 zeolites have been synthesized; the most common are zeolites A, X, Y, and ZMS-5. Natural and synthetic zeolites are used commercially because of their unique adsorption, ion-exchange, molecular sieve, and catalytic properties.

Natural Zeolites

Commercial zeolite deposits in the United States are associated with the alteration of volcanic tuffs in alkaline lake deposits and open hydrologic systems. Commercial deposits in the United States are in Arizona, California, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Wyoming. Zeolites in these deposits are chabazite, clinoptilolite, erionite, mordenite, and phillipsite. Other components, such as orthoclase and plagioclase feldspars, montmorillonite, opal, quartz, and volcanic glass, are present in some deposits.

Production.—Conventional open pit mining techniques are used to mine natural zeolites. The overburden is removed to allow access to the ore. The ore may be blasted or stripped for processing by using front-end loaders or tractors equipped with ripper blades. In processing, the ore is crushed, dried, and milled. The milled ore may be air-classified as to particle size and shipped packaged in either bags or bulk. The crushed product may be screened to remove fine material when a granular product is required, and some pelletized products also are produced. Producers also may modify the properties or blend their zeolite products with other materials prior to sale to improve their performance.

Domestic data for natural zeolites were collected by means of a voluntary survey of the domestic mining industry. Survey forms were sent to nine companies with responses accounting for approximately 90% of the production and consumption data.

Eight companies mined natural zeolites in the United States in 2000. Three other producers did not mine zeolites during the year but sold from stocks or purchased zeolites from other producers for resale (table 1). Chabazite was mined in Arizona and Nevada; clinoptilolite was mined and processed in California, Idaho, Nevada, New Mexico, Oregon, Texas, and Wyoming; and mordenite was mined in Nevada. The largest producing State was New Mexico. Total domestic production of zeolites was estimated to be 41,800 metric tons (t) compared with an estimated 43,000 t in 1999.

GSA Resources, Inc., announced plans to acquire or collaborate with other suppliers of specialty minerals. The company's intent was to produce entire systems, rather than single products, that can be used for remediation of hazardous wastes, odor control, and other sorption applications (North

Zeolites in the 20th Century

The mining of zeolites is a recent activity compared to many other mineral commodities. In 1900, there was no commercial mining of natural zeolites. Sustained mining of natural zeolites did not begin until the early 1970s. The delay in the start of zeolite mining can be attributed mainly to the fact that, prior to the 1950s, natural zeolites were originally considered to be mineralogical curiosities that filled vugs and fractures in igneous rocks, and commercial deposits were not known. In the late 1950s, large deposits of zeolite-rich volcanic tuffs were discovered in the western United States. Between 1950 and the mid-1980s, many large mining and petroleum companies conducted exploration programs. While these programs uncovered additional reserves, markets for natural zeolites did not develop as anticipated, and only a few hundred tons of zeolites were mined annually through the mid-1970s. By the mid-1980s, annual production and sales of natural zeolites were still below 10,000 metric tons, so the major companies withdrew from the industry. Companies better suited to small-scale mining then stepped in and have slowly developed the natural zeolite market into the small yet sustainable industry that exists today.

In 2000, there were 41,800 tons of natural zeolites mined in several States in the Western United States. This is about triple the production and sales in the 1980s but less than the peak production and sales of 53,000 tons attained in 1994. Even with the short mining history, the industry has shifted its focus. Initially, zeolites were treated as bulk commodities, with producers seeking large volume markets. Pet litter applications, for which zeolites were well suited, became the mainstay of the industry, representing more than 50% of sales of natural zeolites annually in the mid-1980s. Producers, however, realized that low-value bulk sales of zeolites could not sustain the industry forever and began developing value-added applications. As a result, pet litter markets, while still important, commanded a far smaller share of the overall market in 2000, with the growth of horticultural (soil conditioners and fertilizer carriers), animal feed, waste water treatment, desiccant, water purification, and gas absorbent markets.

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American Minerals News, 2000b). Centre Capital rescinded its purchase of American Absorbents Natural Products, Inc. (AANPI), from Equitable Assets Inc. The transaction was to have involved the exchange of one million shares of Centre Capital stock valued at more than $11.3 million. AANPI, one of the larger producers of zeolite-based cat litter, still holds its zeolite deposit in Oregon (Moore, 2000; North American Minerals News, 2000c).

Consumption.—An estimated 30,900 t of natural zeolites was sold in 2000 in the United States compared with an estimated 35,000 t in 1999. Natural zeolites were sold for, in decreasing order by tonnage, pet litter, animal feed, horticultural applications (soil conditioners and growth media), wastewater cleanup, odor control, fungicide or pesticide carriers, desiccants, gas absorbents, catalysts, water purification, aquaculture, and oil absorbents. Pet litter, animal feed, and horticultural applications accounted for more than 70% of the domestic sales tonnage. Sales to individual markets did not change significantly compared with those of 1999.

Prices.—Prices for natural zeolites varied with zeolite content and processing. For industrial or agricultural applications, prices ranged from $30 to $70 per metric ton for granular products down to 40 mesh and from $50 to $120 per ton for finer (-40 to -325 mesh) ground material (Holmes, 1994, p. 1150-1151). For such products as pet litter, fish-tank media, or odor control applications, prices ranged from $0.50 to $4.50 per kilogram. Quoted prices should be used only as a guideline, because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade.—Although trade data for natural zeolites are not available, imports of natural zeolites were estimated to be less than 100 t, and exports were estimated to be less than 200 t in 2000. The bulk of the international trade appears to be in synthetic zeolites.

World Review.—Worldwide production of natural zeolites was estimated to be between 3 million and 4 million metric tons (Mt) based on reported production by some countries and production estimates published in trade journals. Estimates for individual countries were China, 2.5 Mt; Cuba, 500,000 to 600,000 t; Japan, 140,000 to 160,000 t; the United States, 41,800 t; Hungary, 10,000 to 20,000 t; Slovakia, 12,000 t; Georgia, 6,000 t; New Zealand, 5,000 t; Greece, 4,750 t; Australia, Canada, Italy, and other republics of the former Soviet Union, 4,000 t each; Bulgaria, 2,000 t; and South Africa 1,000 to 2,000 t. Small amounts of natural zeolites also were produced in Argentina, Germany, and Indonesia.

Australia.—Talon Resources NL announced plans to develop horticultural and environmental products that were zeolite-based. The company has made its first sales to the agricultural market. The company also commissioned a zeolite production plant in Duaringa, Queensland (Countryman, 2000).

Canada.—C_2C Mining Corp. completed an animal feed study with Klok Feeds, which raises 40,000 feeder hogs annually. The zeolite was mixed with the feed ingredients, replacing the bentonite and lignite sulfinate binders normally used. The study revealed that the addition of zeolites in the feed reduced odors and increased feed conversion rates. C_2C also worked with Amoco Canada Petroleum Co. Ltd. to conduct soil remediation tests using zeolites. Plans are to bring the C_2C deposit into production by the end of 2001. C_2C also signed an agreement with Zeo-Tech Enviro Corp., which holds the rights to a zeolite deposit near Princeton, British Colombia. C_2C will hold a 25% interest in the zeolite holdings and a new processing plant that is expected to be constructed by the end of 2001. In return, Zeo-Tech Enviro will have access to C_2C's patented processing methods for specialty zeolite products and will receive a 25% share of C_2C's zeolite properties near Kentville, Nova Scotia (North American Minerals News, 2000a).

Ukraine.—The Government of Ukraine has placed a 25% share of Zatissyansky Chemical Plant up for sale. The Government owned about 60% of the company. Zatissyansky Chemical is the only Ukrainian producer of zeolite powders (Industrial Minerals, 2000).

Current Research and Technology.—Researchers examined the exchange of sodium by cesium and strontium in analcime-bearing assemblages. The exchange was conducted at 250° C to 300° C and 39.7 to 85.8 bars of pressure in pure water and chloride solutions. A continuous solid solution between sodium and cesium and sodium and strontium did not occur. Thermodynamic calculations indicated that leaching would be minimized at about a pH of 8, suggesting that an analcime-albite-paragonite assemblage may act as a barrier to the migration of cesium and strontium from radionuclide-contaminated materials. This is an important consideration for underground storage of high-level radioactive wastes (Redkin and Hemley, 2000).

Synthetic Zeolites

Catalysts.—Lurgi GmbH designed a fixed-bed catalytic cracker that can be incorporated into a naphtha steam cracker system. The fixed-bed system converts olefins into propylene and ethylene. The system is reported to convert 60 weight percent of C_4 and C_5 components from the steam cracker directly to propylene. Pilot plant studies are planned by Linde Division, Union Carbide Corp., who licensed the process from Lurgi. The catalytic cracker uses ZMS-5 zeolite in a fixed bed at 500° C and 1 to 2 bars to make the conversion. Coking and polymer formation are reduced through the introduction of steam. Cycle times are several weeks, and anticipated zeolite life is 15 months (European Chemical News, 2000b).

The Institut Francais du Petrole developed a new zeolite-based isomerization catalyst. The catalyst is reported to increase paraxylene yield to 93% compared with 88% with typical mordenite-based catalysts. Pilot plant testing has shown that paraxylene yield losses were reduced by 40% to 50%. The system also can operate under milder operating conditions, reducing operating and capital costs (European Chemical News, 2000a).

Detergents.—There was an estimated 1.04 Mt of synthetic zeolite used worldwide in detergents in 1998. This represents the largest volume segment of the synthetic zeolite market. In the United States, demand for powder detergents has declined. Liquid detergents surpassed powder detergents for the first time in 1998. Powders are still preferred in Europe but have lost some popularity with the consuming public. The declining demand, coupled with additional capacity that came online in the early 1990s, has resulted in overcapacity in Japan, North

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America, and Western Europe; projected growth in detergent uses in these markets is -1%, -2%, and 0.4%, respectively (LePree, 2000). In Western Europe, zeolites were estimated to account for 75% of the builder market for home laundry detergents with phosphates making up the remaining 25%. Builders are used to reduce water hardness. The decision to allow phosphate-based detergents to carry the European Union's "eco-label" resulted in market gains in 1999. Despite gains in Asia, phosphate-based detergents may be threatened by new legislation to remedy lake eutrophication, the process of excess nutrients promoting plant growth at the expense of animal life, in some regions in China. If demand for zeolite builders grows in China, plants in Southeast Asia will supply that market (Chemical & Engineering News, 2000b).

Molecular Sieves.—PQ Corp. announced that it would withdraw from the molecular sieve adsorbent market in 2000. The company cited excess supplies and consequent marginal returns for the withdrawal. PQ will continue to supply synthetic zeolites for adsorption and separation, detergents, and chemical and petrochemical applications (Walsh, 2000).

Tricat Zeolites GmbH constructed a new plant in Bitterfield, Germany, for manufacturing zeolites and sieves (European Chemical News, 2000d).

Current Research and Technology.—Demand for catalysts for petroleum refining is expected to increase at a rate of 1.9% per year between 1998 and 2003 as the demand for petroleum increases. One of the issues facing refiners is the reduction in the permissible sulfur content of gasoline. In 1999, the U.S. Environmental Protection Agency proposed reducing sulfur limits from 330 parts per million (ppm) to 30 ppm. Similarly, in Europe, proposed regulations will limit permissible sulfur content to 150 ppm in 2000 and 50 ppm in 2005. Emphasis is being placed on fluid catalytic cracking (FCC) units because FCC products contribute more than 90% of the sulfur in gasoline. Hydrocracking the FCC feed can reduce sulfur content but is expensive. Despite this, predictions were for growth in precious metals and zeolites for hydrocracking to increase. Another approach is to convert some of the sulfur species into forms that are more easily removed from gasoline. For example, catalysts that result in reaction pathways that lead to the formation of hydrogen sulfide would reduce sulfur in gasoline. Another approach is to develop catalysts that react with specific sulfur compounds that are difficult to remove from gasoline, such as benzothiophene. There also is a need to reduce olefin content of gasoline in response to new environmental regulations. Modified FCC catalysts and ZMS-5 zeolite have been used to control olefin content (European Chemical News, 2000c; Oil & Gas Journal, 2000a).

A mesoporous (large pore structure) zeolite catalyst has been developed by Haldor Topsoe Research Laboratories of Denmark for the epoxidation of cyclohexene. The zeolite structure contains titanium cations and, with the mesoporous structure, is chemically more active than conventional titanium-containing zeolite catalysts. The zeolite is prepared using an excess zeolite gel and a carbon matrix. The carbon is removed after synthesis by combustion (Chemical & Engineering News, 2000c).

A study was conducted on erosion of the FCC unit by FCC catalysts. FCC catalysts, typically composed of aluminum and silica, can erode portions of the FCC unit not properly protected by linings. Attrition resistance was one characteristic that was considered critical. Attrition-resistant particles resulted in generation of fewer fine particles and fewer sharp-edged, irregular particles that are created when larger particles fracture. Attrition of the catalyst can result in particle losses in some FCC units, while those units designed to minimize fines loss will experience an increase in particle bulk density. Sharp, irregular particles erode the FCC unit more rapidly than spherical particles. The study also showed that increased cyclone velocity magnifies attrition rates and is influenced by particle density and size. In general, higher particle densities and smaller sizes tended to reduce erosion rates (Oil & Gas Journal, 2000b).

Scientists take advantage of the rigid structure and the pores and channels of zeolites to control the reactions. The pores and channels define the size of the molecules that can form and diffusion rates within the structure and even cause selective orientation of the molecules within the structure so that only one face of a molecule can react (Chemical & Engineering News, 2000a). For example, scientists at Tulane University in New Orleans working with researchers at the University of British Columbia in Vancouver created a stable chiral zeolite structure by loading an existing zeolite structure (zeolite Y) with chiral organic molecules. Previously, researchers had unsuccessfully attempted to synthesize the chirally modified zeolite structures. The use of the modified zeolite structure resulted in a high stereoselectivity during the reaction process. Sodium in the Y zeolite was found to be critical. When cesium, lithium, and potassium were exchanged for the sodium, enantiomeric excesses decreased. The chirally-modified zeolite structure will be used to synthesize molecules that are normally difficult to form and also to produce odd-shaped and highly strained chemical species (Chemical & Engineering News, 2000d).

Research continued on the use of zeolites to remove nitrogen oxides (NO_x) from automobile exhaust. Chemists at the Catholic University of Leuven in Belgium, used the sodium variety of zeolite Y to absorb NO and NO_2 as dinitrogen trioxide (N_2O_3) from engines that use excess air to reduce carbon dioxide emissions. Barium oxides used in lean-burn engines work best with very low sulfur fuels. The zeolite Y absorbent is not affected by the presence of sulfur oxides, and the absorption process can be reversed. This suggests the possibility of recirculated trapped NO_x into the intake air so it can be converted to nitrogen gas during the combustion process (Chemical & Engineering News, 2000e).

Outlook

Market growth for natural zeolites will continue to be slow. Growth in the major market, pet litter, has been slight for the past few years and is not expected to increase significantly. Domestic sales of natural zeolites probably will be between 30,000 t to 35,000 t for the next few years. Pet litter probably will remain the largest market. As it has for the past few years, low-tonnage niche markets should offer opportunities for producers to introduce high-unit-value products, particularly for environmental applications. Markets for synthetic zeolites in the United States will slow. Detergents sales have stagnated

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and possibly declined slightly in recent years. Sales in Europe also may slow as phosphate-based detergents regain acceptance. Possible growth can occur in China depending on the effectiveness of new legislation discouraging phosphate builder use. Projections for growth in the catalyst for petroleum refinery market are positive with the anticipated growth in demand for gasoline worldwide.

References Cited

Chemical & Engineering News, 2000a, Boxed in—Chemistry in confined spaces: Chemical & Engineering News, v. 78, no. 34, August 21, p. 40-47.

———2000b, Builders market is influenced by detergent forms: Chemical & Engineering News, v. 78, no. 4, January 24, p. 43.

———2000c, Novel zeolite enhances catalytic epoxidation: Chemical & Engineering News, v. 78, no. 46, November 13, p. 28.

———2000d, Photochemistry with a twist inside zeolites: Chemical & Engineering News, v. 78, no. 6, February 7, p. 10-11.

———2000e, Zeolite removes NO_x from motor exhausts: Chemical & Engineering News, v. 78, no. 35, August 28, p. 22.

Countryman, 2000, Horticulture push—Supersorb focuses on zeolite products: Countryman [Perth], June 15, p. 30.

European Chemical News, 2000a, IFP develops high yield catalyst: European Chemical News, v. 72, no. 1902, March 27-April 2, p. 47.

———2000b, Propylur route boosts propylene production: European Chemical News, v. 72, no. 1902, March 27-April 2, p. 47.

———2000c, Rising to the challenge: European Chemical News, v. 72, no. 1901, March 20-26, p. 23-27.

———2000d, Tricat plant ready: European Chemical News, v. 72, no. 1908, May 8-14, p. 30.

Holmes, D.A., 1994, Zeolites, *in* Carr, Donald, ed., Industrial minerals and rocks (4th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., p. 1129-1158.

Industrial Minerals, 2000, Sale of 25% stake in zeolite/barytes company: Industrial Minerals, no. 399, December, p. 23.

LePree, Joy, 2000, Changing trends in builders: Chemical Market Reporter, v. 257, no. 4, January 23, p. FR12.

Moore, Paul, 2000, Not to be sniffed at—U.S. and European cat litter markets reviewed: Industrial Minerals, no. 399, December, p. 61.

North American Minerals News, 2000a, C_2C zeolites delivering the bacon—Animal feed applications take off: North American Minerals News, no. 67, December, p. 1.

———2000b, GSA seeks growth through acquisition: North American Minerals News, no. 60, May, p. 5.

———2000c, Zeolite purchase rescinded: North American Minerals News, no. 67, December, p. 3.

Oil & Gas Journal, 2000a, Refining catalyst demand: Oil & Gas Journal, v. 98, no. 41, October 9, p. 64-66.

———2000b, FCC catalyst properties can affect cyclone erosion: Oil & Gas Journal, v. 98, no. 1, January 3, p. 33-36.

Redkin, A.F., and Hemley, J.J., 2000, Experimental Cs and Sr sorption on analcim in rock-buffered systems at 250-300° C and P (sub sat) and the thermodynamic evaluation of mineral solubilities and phase relations: European Journal of Mineralogy, v. 12, no. 5, p. 999-1014.

Walsh, Kerri, 2000, PQ exits molecular sieve adsorbents: Chemical Week, v. 162, no. 47, December 20-27, p. 12.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publication

Zeolites in Sedimentary Rocks. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

British Zeolite Association.

The Economics of Zeolites. Roskill Information Services Ltd., 1995.

International Committee on Natural Zeolites.

International Zeolite Association.

Mining Engineering.

Natural and Synthetic Zeolites. U.S. Bureau of Mines Information Circular 9140, 1987.

TABLE 1
DOMESTIC ZEOLITE PRODUCERS AND SUPPLIERS, 2000

State and company	Type of zeolite
Arizona:	
GSA Resources, Inc.	Chabazite.
UOP Inc.	Do.
California, KMI Zeolite, Inc.	Clinoptilolite.
Idaho, Steelhead Specialty Minerals, Inc.	Do.
Nevada:	
Ash Meadows Zeolite, LLC	Do.
Moltan Co.	Chabazite/mordenite.
New Mexico, St. Cloud Mining Co.	Clinoptilolite.
Oregon:	
American Absorbents Natural Products, Inc.	Do.
Teague Mineral Products Co.	Do.
Texas, Zeotech Corp.	Do.
Wyoming, Addwest Minerals International Ltd.	Do.

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ZINC

By Jozef Plachy

Domestic survey data and tables were prepared by Aaron J. Poyer, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2000, domestic zinc mine production, expressed in zinc content of ore, increased by nearly 2% from that of 1999, mainly due to increased production in Alaska and Missouri (table 1). On the basis of recoverable content and annual average U.S. price, the value of zinc mine production was estimated to be about $1 billion. Zinc was extracted from 19 mines in 6 States by 8 companies (tables 2, 3). For the 10th consecutive year, Alaska was the leading zinc mining State, followed by, in descending order, Tennessee, Missouri, and New York. In 2000, as in every year since the opening of the Red Dog Mine in 1989, U.S. mine production greatly exceeded smelter capacity (table 6), necessitating exports of concentrate. More than one-third of exports, which were supplied entirely by the Red Dog Mine, was trucked to the Trail smelter in Canada; the remaining two-thirds went mainly to Asian markets (table 14). Primary zinc metal production by the three primary smelters decreased by more than 5% in 2000 (tables 4, 6).

Apparent consumption of refined zinc metal in 2000 decreased nearly 2%, owing to the slowdown of the economy. Of the total refined zinc metal consumed in the United States, about one-half was used for galvanizing, followed by use in zinc-based alloys and in brass and bronze (table 11). Zinc compounds and dust were used principally by the agricultural, chemical, paint, and rubber industries.

The average U.S. producer price for refined zinc in 2000, which was based on the London Metal Exchange (LME) daily cash price plus premium, increased by about 5% to $1.13 per kilogram (51.15 cents per pound).

World production of zinc concentrate by 41 countries increased by about 9% in 2000, to more than 8.7 million metric tons (Mt). The largest producers were, in decreasing order of magnitude, China, Australia, Canada, Peru, and the United States (table 17). World smelter production increased by nearly 6%, to about 9 Mt. The largest producer of zinc metal was China, followed by Canada, Japan, Australia, the Republic of Korea, Spain, and the United States (table 18).

Legislation and Government Programs

In January 19, 2000, the U.S. Environmental Protection Agency (EPA) finalized the Clean Water Act (CWA) establishing national, technology-based effluent limitations and pretreatment standards for waste water discharges associated with the operation and maintenance of new and existing hazardous and nonhazardous landfill facilities regulated under the Resource Conservation and Recovery Act (RCRA). Because of an insufficient amount of contained biologically degradable organic material in the leachate of inorganic landfills, EPA concluded that the alternative technology of chlorination and use of granual activated carbon is as effective and economically achievable as the biological treatment of nonhazardous landfills containing biodegradable material. The proposed CWA limits zinc in nonhazardous landfills to a monthly average of 0.11 milligram per liter (mg/L) and a daily maximum limit of 0.20 mg/L. EPA estimated that the final CWA should remove about 400 metric tons per year (t/yr) of pollutants at an estimated annual cost of $7.6 million (U.S. Environmental Protection Agency, 2000).

In 1998, the U.S. Geological Survey conducted a study to determine how much copper, gold, lead, silver, and zinc is undiscovered in the United States not more than 1 kilometer (km) below the Earth's surface. These commodities were chosen because they are the most valuable metals, after iron and aluminum, and because they usually occur together in nature. Partially based on the 1973 study by Wedow and others (1973), the estimate of the amount of zinc in undiscovered deposits ranged from greater than130 Mt at a 90% probability to greater than 290 Mt at a 10% probability. Nearly 40% of the zinc was

Zinc in the 20th Century

By the beginning of the 20th century, the United States was the leading world zinc metal producer, a position held for most of the next 70 years. Mostly zinc sulfide (sphalerite) ore was crushed, washed, and subjected to gravity separation. About 65% of zinc metal was produced in Missouri, with smaller quantities produced in Colorado and New Jersey (from non-sulfide ore). In 1900, domestic production of zinc metal reached about 112,400 metric tons, 18% of which was exported. Consumption reached 90,200 t, about 50% of which was used in galvanizing, 26% was used in brass, and 17% was used to produce sheet metal.

During the next 100 years, new beneficiation processes, mainly flotation, increased zinc metal recovery up to 87%. Advancements in retort smelting and the introduction of electrolytic processing increased efficiency of zinc metal production while reducing air pollution. Increasingly stringent environmental laws, however, made the building of new domestic smelters more costly. Consequently, by 2000, the United States had only three primary smelters producing 228,000 tons of zinc metal. With another 143,000 tons of secondary zinc, U.S. production accounted for only about one-fourth of its consumption. The remaining zinc for U.S. consumption was imported, mainly from Canada. The United States was the second largest consumer of zinc in the world, with a cumulative total use of 1.32 million tons of zinc metal. Of that total, about 57% was used in galvanizing; 17%, in zinc-based alloys; and 13%, in brass and bronze.

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thought to be contained in the Mississippi Valley-type deposits, followed by sedimentary-exhalative deposits (31%), volcanogenic massive sulfide deposits (15%), and other deposits (14%) (U.S. Geological Survey, 1998). During the past 20 years, sedimentary-exhalative deposits have grown in importance because they usually occur in well-defined areas and are characterized by large tonnages and high grade, allowing for the development of large-capacity mines. These deposits, unfortunately, are usually fine-grained and metallurgically difficult to treat.

Production

Mine Production.—The Red Dog area in Alaska is considered the most significant zinc district in the world. Accordingly, Cominco Ltd. spent 36% of its total exploration expenditure ($33 million) in this area in 2000. Most of the drilling was carried out to delineate the Anarraaq deposit, which was discovered in 1999, 10 km northwest of Red Dog. The deposit is estimated to contain 17.2 Mt of inferred resources grading 15.8% zinc, 4.8% lead, and 71 grams per ton (g/t) silver. Together, the five deposits at Red Dog—Anarraaq, Aqqaluk, Main Zone, Paalaaq, and Qanaiyaq—have total resources of 148 Mt grading 16.6% zinc, 4.5% lead, and 85 g/t silver (Cominco Ltd., 2001).

In February 2000, Cominco Alaska Inc., subsidiary of Cominco Ltd. of Canada, began a $90 million Mill Optimization Project (MOP) designed to bring the mill at the Red Dog Mine up to its full operational potential. The project will include an upgrade of existing water treatment capacity, a new large-capacity zinc thickener, a major addition to flotation capacity and backup power generation, and enlargement of fuel storage capacity. These improvements will allow Cominco Alaska to produce 1.1 million metric tons per year (Mt/yr) of zinc concentrate, at a 87% recovery rate by the second half of 2001. Comparable figures for 2000 were 959,800 t of concentrate, containing 55.3% zinc, and average mill recovery rate of 83%. Increased production at the Red Dog Mine will partly compensate for planned closures of Cominco's Polaris and Sullivan mines in Canada (Platt's Metals Week, 2000c).

In September, Cominco approved the reopening of the Pend Oreille zinc-lead mine in Washington State, near Metaline Falls north of Spokane near the British Columbia (BC) border and about 50 km south of Cominco's Trail smelter in BC, Canada. The $70 million project should be finished by September 2002 and is expected to produce 84,000 t/yr of zinc concentrate and 13,000 t/yr of lead concentrate for at least 10 years (Cominco News, 2001). In 1995, when Cominco acquired the property from Resource Finance Corp. (RFC), it contained reserves of 5.3 Mt grading 7.3% zinc and 1.3% lead (Platt's Metals Week, 2000f). The first recorded shipment of ore from the Pend Oreille property dates back to 1906. Production was sporadic until 1930 when a 300-ton-per-day (t/d) flotation mill was built on-site. The mill was later expanded, and in 1951 the existing 2,400-t/d mill was built. The Bunker Hill Co., which had acquired the project from the mine founder, Pend Oreille Mines & Metals Inc., in 1974, closed the mine in 1977, following a labor dispute at its electrolytic plant in Idaho. Pintlar Corp., a wholly owned subsidiary of Gulf Resources & Chemical Co., acquired Pend Oreille and optioned the property to RFC in 1988. In 1996, Cominco bought RFC, including the Pend Oreille Mine (Northern Miner, 2000a). During 2000, an extensive drilling program outlined a 2-Mt resource at Washington Rock, 2 km southwest of the existing mine (Cominco Ltd., 2001).

Grupo Mexico S.A. de C.V. announced in December that it has completed the organization of a new, U.S.-based mining and minerals subsidiary, which will operate under the name of Americas Mining Group (AMG). The reorganization was triggered by the acquisition of ASARCO Inc. in November 1999. AMG includes not only Grupo's interest in Asarco, but also Southern Peru Copper Corp. and Grupo Minero Mexico. It will also include separate purchasing and sales offices. The new subsidiary will be staffed by personnel from the existing Grupo Mexico units and will be headquartered in Phoenix, AZ. After the merger with Asarco, Grupo Mexico became a diversified mining and transportation company that ranks internationally as the fifth largest zinc producer. Its zinc interest includes three zinc mines in Tennessee (Coy, Immel, and Young) (ASARCO Inc. News, 2000).

Zinc concentrate production at Doe Run Resources Corp.'s Missouri mining complex was reduced following production changes prompted by events primarily in the lead market. After closing its West Fork and Viburnum mills in May, Doe Run began shipping ore from West Fork to the Fletcher mill and put the Viburnum #29 Mine on care and maintenance and reduced production at the Viburnum #28 Mine. Because of the closure of the Viburnum mill, ore from the Casteel Mine was transported to the Buick mill. Before all these changes, Doe Run's Missouri complex produced about 52,000 t of zinc in concentrate and about 338,000 t of lead in concentrate in 1999 (CRU International Ltd., 2000c).

Exploration.—Cypress Development Corp. has completed the third phase of exploration at the Gunman zinc oxide property in northeastern Nevada. Results of drilling indicated grades of up to 20% zinc and 171 g/t silver. Since the results far exceeded the company's expectations, a fourth phase of drilling was being planned (Mining Journal, 2000f).

In January 2001, Denver-based Summo Minerals Corp. received all assays from an 18-hole drilling program completed by yearend 2000 at the Doctor Mine zinc property in Colorado. The dominant zinc mineral in the intercepts appeared to be smithsonite, and the drilling was interpreted by geologists as a zone of mineralization averaging 15 meters (m) deep, 53 m wide, and 152 m long, with a zinc content of up to 20.7% (Mining Journal, 2001).

Consumption

Since 1993, world consumption of zinc increased every year. It continued in 2000, when world consumption, at 8.8 Mt, was more than 5% higher than 1999. In comparison, the average increase between 1996 and 1998 was only about 1.6%. Slowing worldwide consumption was partially caused by a nearly 2% decline in U.S. consumption in 2000. Because of this decline, the United States was surpassed by China as the world's largest consumer of refined zinc metal. In 2000, the United States consumed 1.32 Mt of zinc, or about 15% of world consumption. Despite falling to second place in consumption, the United States still plays an important role in world zinc markets. Any weakening of U.S. economy would not only decrease consumption of zinc on the domestic market but it could

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threaten the fragile economies of some Asian countries who are disproportionately dependent on exports to the United States.

According to the International Lead and Zinc Study Group, despite growing worldwide demand for zinc in 2000, production exceeded consumption by about 130,000 t, compared with a small deficit in 1999. In the Western countries, the zinc metal deficit in 2000 amounted to 815,000 t. This deficit was more than offset by imports, mainly from China, which alone exported 561,000 t of zinc metal (International Lead and Zinc Study Group, 2001a, c).

Stocks

Producers, consumers, merchants, the LME, and the U.S. Government maintain stocks of zinc metal. The surplus production of 130,000 t in 2000, had little effect on these stocks. After several consecutive years of market deficit, the draw down of LME stocks continued in 2000; by the end of December it fell to 195,000 t from 291,000 t at the beginning of 2000. The only stocks that increased in 2000 were in consumers' and merchants' warehouses. By the beginning of 2001, the overproduction of zinc metal during the previous year began to show in expanding stocks at all levels, except at the U.S. Government stockpile (International Lead and Zinc Study Group, 2001b).

Prices

Zinc concentrate production cost in the Western world's major mining countries in 2000 ranged between 29 cents per pound of contained zinc in Ireland to 39.5 cents per pound in the United States (Roskill Information Services Ltd., 2001, p. 49). In comparison with 1999, the average zinc metal cost increased by an estimated 10%, owing to higher concentrate treatment charges and reduced byproduct credits. These higher charges at smelters, plus increased fuel prices, have more than offset a continuing decline in mining and labor costs in many countries (Mining Journal, 2000h). The increase in zinc metal production cost, however, had no effect on zinc metal prices. From a level which was already hard to justify against declining stocks, zinc prices dropped further as worries over the probability of a world economic slowdown increased. In the United States, the composite price for North American Special High Grade zinc declined by nearly 9% from January to December 2000. The decline in price intensified during the past 4 months when the U.S. economy began slowing down. From September 2000, when the price reached 60.04 cents per pound, the highest for the year, it declined to 52.57 cents per pound by the end of December.

World Review

Australia.—The Australian Bureau of Agricultural and Resource Economics (ABARE) reported an 11% increase in the gross value of Australia's mine production in fiscal year (FY) 2000 (ended June 30). Increased investment in mining operations and exploration prior to FY 1998, as well as rising commodity prices and an upturn in global economic growth, contributed to an increase in production of almost all minerals. Substantial increases in production are forecast for the next fiscal year; one of the largest increases (nearly 20%) is expected to be in the production of zinc in concentrate. Increased production will be reflected in increased metals and minerals exports, which are anticipated to rise in FY 2001 by 13%. New capital investment fell by about 40% in FY 2000, and is forecast to fall a further 6% in FY 2001. There was a similar decline in exploration expenditures, which could have been the result of cost-cutting measures by producers uncertain of the long-term price outlook. According to ABARE, the medium-term outlook (for the next 5 years) for the mining industry is not promising. Export earnings are expected to be placed under downward pressure by the steady appreciation of the Australian dollar from its current historic low (U.S. Embassy, 2000).

The Premier of Queensland officially opened Pasminco Ltd.'s Century zinc mine on April 4, 10 years after the first exploration drill-holes intersected significant mineralization. The Century deposit, which is 250 km from Mount Isa in the most northern part of Queensland, now supports the world's largest zinc mine. The final development cost was $498 million, about 10% below budget. The first 10,000 t of zinc concentrate, produced from the development ore, was shipped to Pasminco's Budel smelter in the Netherlands in December 1999. By mid-April 2000, 100,000 t of high-grade concentrate was shipped to the Budel smelter. Shipments to other customers began in May. At full output, Century will produce 500,000 t/yr of zinc in concentrate (Platt's Metals Week, 2000e). The concentrate will be pumped through the 304-km-long pipeline to the Gulf of Carpentaria. From there, about one-half of the concentrate will be shipped to the Budel smelter and the rest to various smelters, mostly in Asia.

At the same time as the Century Mine is reaching full capacity, preparations are underway to close its century-old zinc mining operations at Pasminco's Broken Hill area in New South Wales. As a prelude to the impending closure in 2006, 52 jobs will be eliminated by the end of April 2000, reducing the number of miners to less than 600 for the first time since the mine opened (American Metal Market, 2000b).

Western Metals Ltd. will spend $6.7 million to expand the Pillara mining complex, in the Kimberley region of Western Australia. Western Metals' overall zinc production will likely remain the same because the increased production at Pillara will be offset by the closure of the Hallyer zinc-lead mine and pending closure of the aging concentrator at Cadjebut. The expansion of the Pillara concentrator from 1.5 Mt/yr to 2.4 Mt/yr of ore processing capacity is expected to reduce the annual cost of beneficiation by some $3.2 million. In addition, Western Metals expects ore from the deeper deposit to have a much higher grade, so that contained metal output is likely to rise substantially. Samples from greater depth showed mineralization as high as 12% zinc, compared with the current 8.4%. Production at the Pillara Mine is to rise by 20% to 1.8 Mt/yr of ore; the remaining 0.6 Mt of ore, needed for the expanded concentrator, will be trucked in from the nearby Western Metals' Kapok Mine (Metal Bulletin, 2000o).

Work on the George Fisher project in Australia continued in 2000 with upgrading of the existing lead-zinc concentrator. Capacity of Mount Isa, 22 km south of George Fisher, was expanded to 2.5 Mt/yr, and its regrinding, cleaning, and thickening processes were upgraded. During testing, recoveries reached 73.4% for zinc and 78.8% for lead. Limited production from the George Fisher Mine began at the end of 2000, 6 months ahead of schedule. At full capacity, the mine will

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produce 170,000 t/yr of zinc in concentrate (Mining Journal, 2000e).

Kagara Zinc Ltd. of Australia has secured a second expansion deal for its Mount Garnet zinc project in northern Queensland. The company signed an agreement with Lachlan Resources NL to acquire 100% interest in the Balcooma project 120 km southwest of Mount Garnet and 230 km northwest of Townsville, where Korea Zinc Co. Ltd.'s new zinc smelter/refinery is located. The new acquisition included the high-grade Surveyor 1 zinc-lead deposit, which Kagara immediately incorporated into its current development plans for Mount Garnet. About 87% of the 659,000 t of resource was classified in the measured category and contained 16.7% zinc, 6.7% lead, 1% copper, 142 g/t silver, and 1 g/t gold. The deposit will initially be mined as an open pit, with the ore being trucked to nearby Mount Garnet for processing. The cash payment for Balcooma was $3 million plus a convertible loan note valued also at $3 million. If converted, Lachlan would own a 15% stake in Kagara. Kagara also negotiated an option to acquire a 100% interest in the nearby Muldiva property from a consortium that includes Barramundi Gold Ltd. and a number of prospectors. Muldiva comprises three exploration licenses covering 330 square kilometers (km^2), about 100 km north of Mount Garnet. At the beginning of the year, when Kagara bought a 75% interest in the Mount Garnet project, it also acquired a 75% interest in the nearby King Vol deposit from Perilya Ltd. (Mining Journal, 2000g). At this stage, Kagara intends to treat about 500,000 t of ore from Mount Garnet and Balcooma and produce about 40,000 t of zinc in concentrate to be trucked to the Townsville plant.

According to Sun Metals Corp., subsidiary of Korea Zinc Co. Ltd., the Townsville smelter/refinery in Australia achieved its nameplate capacity of 170,000 t by yearend 2000, despite only having opened in November 1999. Planned expansion, which would double the capacity, will depend on the availability of inexpensive power and on high price for zinc. Because the main market for Sun Metals' zinc is Southeast Asia, where the economy has not yet fully recovered, expansion is unlikely to take place for at least 5 years. Sun Metals sources its concentrates from four mines, the Century, Mount Isa, and Pillara Mines in Australia and the Red Dog Mine in Alaska (Metal Bulletin, 2000l).

Brazil.—Brazilian zinc producer, Cia Paraibuna de Metais, is planning a $100 million expansion of its Juiz de Fora smelter that would more than double zinc production over the next 3 years. The first step, which has already begun, is the debottlenecking project that will increase production from the current 77,000 t/yr to 86,000 t/yr. The major part of the expansion, to reach 170,000 t/yr of refined zinc, involves building of two new power plants of 50 and 40 megawatt capacity. A $1.77 million feasibility study is already underway. On completion of the feasibility study, the Brazilian Government will offer a tender for the construction of the two powerplants. Production at Cia Mineria de Metais' Tres Maria, the second of two Brazilian smelters, is also to increase from 120,000 t/yr to 160,000 t/yr by 2002. Although three new galvanizing plants will come on-stream in 2001, the anticipated increase of domestic consumption may not be enough to absorb the increased output of both refineries. Consequently, some of the refined zinc will probably be exported (Metal Bulletin, 2000j).

Canada.—In June 2000, Expatriate Resources Ltd. of Vancouver acquired 100% of Cominco Ltd.'s interest in some 2,800 mineral claims in the Finlayson Lake volcanogenic belt in southeast Yukon Territory, including the Kudz Ze Kayah polymetallic deposit. The purchase cost $1 million in cash and $10 million in convertible debentures is to be repaid over 4 years, with $1 million payable in each of the first 3 years and the remainder due on the fourth anniversary of the purchase (Northern Miner, 2000c). In addition to the claims, the purchase included Cominco's water license for development of Kudz Ze Kayah, the surface lease for an access road, and an agreement with indigenous local groups. The purchase allows Expatriate to combine these newly acquired deposits with its 60%-owned Wolverine deposit, to form a single exploration and development project. Expatriate has solved the processing problems associated with the high selenium content of its Wolverine deposit simply by comilling the ore with that of the nearby Kudz Ze Kayah deposit. The two deposits contain an overall resource of 19.2 Mt grading 8% zinc, 1.6% lead, and 1.05% copper, plus gold and silver. Average annual production is anticipated to be about 87,000 t of contained zinc, 13,000 t of lead, and 10,500 t of copper, as well as 1,200 kilograms (kg) of gold and 180 t of silver over the life of the project. The prefeasibility study calls for the upper part of the Kudz Ze Kayah deposit to be mined by an open pit method at the rate of 3,000 t/d. The Wolverine deposit will be developed as a 1,250-t/d underground mine, with the ore trucked 35 km to a processing facility at Kudz Ze Kayah. The concentrate will be trucked 700 km to Skagway, AK, for shipment to smelters in Asia and eastern Canada (Northern Miner, 2000d).

Noranda Inc. of Canada suspended operations at its newly opened Bell-Allard zinc underground mine and mill for a period between February 24 and April 6. The mine, near Matagami, Quebec, was closed because a hoisting skip malfunctioned and damaged the mine's underground shaft compartment. No one was injured in the incident. Operation of Noranda's refinery at Valleyfield was not affected, because sufficient stocks of concentrate existed at the plant. The mine began operation at the start of 2000, reaching 65% of its 2,000 t/d capacity before the accident (Mining Journal, 2000b).

Noranda uncovered a zinc-rich massive sulfide zone during initial exploration in Perseverance, Quebec, near its Bell-Allard zinc mine. Samples from the site's 10 drill holes contained between 13.5% and 25.5% zinc, in addition to 11.8 g/t to 47.1 g/t silver and traces of copper. The Perseverance project is a joint venture between Toronto-based Noranda, which holds a 90% interest, and Societe de Development de la Baie James (SDBJ), which has an option to acquire 10% interest in the mine after completing a positive feasibility study. SDBJ has the option of converting its 10% interest in the mine to a 2% net smelter royalty, leaving Noranda with 100% interest in the mining operations (American Metal Market, 2000a).

Cambior Inc. continued its downsizing by completing the sale of its Bouchard-Hebert and Langlois zinc mines in the Abitibi region of northwestern Quebec to Breakwater Resources Ltd. for $48 million. The transaction, which took place in April 2000, effectively took Cambior out of the zinc business. At the same time, the acquisition gave Breakwater an additional output of copper, gold, and zinc. In addition to copper, Bouchard-Hebert produced a total of 39,100 t of zinc in 1999 and had reserves of 5.3 Mt grading 4.73% zinc. During the same year,

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Langlois produced 31,700 t of zinc in concentrate and had reserves of 5.6 Mt grading 9.45% zinc (Platt's Metals Week, 2000b). Together with other Breakwater mines, the company hoped to produce about 226,000 t of zinc concentrate in 2000 and 258,000 t in 2001 (Metal Bulletin, 2000b). However, by early December, Breakwater suspended operations at its Langlois zinc mine, owing to problems with the main ore transportation system. Together with low metal prices and high treatment charges, the problems made the operation of the mine uneconomic. Immediately after closing the mine, Breakwater begun developing a plan to optimize the life of the mine. The new plan should be completed early in 2001, and the company may begin production by the first quarter of 2002 (Metal Bulletin, 2000c). Since 1995, Breakwater's zinc production expanded more than six-fold, making it the world's eighth largest producer of zinc.

Falconbridge Ltd. of Canada approved deepening of the Kidd Creek Mine at Timmins, Ontario. The mine will be extended by 1,000 m to 3,100 m below the surface at a cost of $430 million. During the first stage, the mine will be extended to 2,700 m. It will involve sinking of a new shaft, installation of a new ventilation, a refrigeration system, and purchase of new underground equipment. Stage one, which should be completed by 2004, would give Falconbridge access to a part of the mine that contains 16 Mt of ore grading 5.74% zinc, 2.82% copper, and 58 g/t silver. Stage two is to begin in 2010. The reserve estimate for that part was 11 Mt of ore grading 5.3% zinc, 2.2% copper, and 100 g/t silver (Mining Engineering, 2000).

Major zinc producer, Billiton Metals Canada Inc., subsidiary of London-based Billiton plc, first agreed but later withdrew from participation in the development of the Howards Pass zinc project (owned by Copper Ridge Explorations Inc.), which straddles the border between the Yukon Territory and the Northwest Territories in Canada. The major attraction of the Howards Pass property is that it is believed to be one of the largest undeveloped zinc deposits in the world, with resources estimated at 110 Mt grading 7.7% zinc, plus lead, cadmium, and silver. Lack of infrastructure and metallurgy pose challenges for development (Metal Bulletin, 2000a). Original prefeasibility evaluation indicated that Howards Pass could not be mined economically, owing to the above mentioned lack of infrastructure and the high cost of traditional milling and smelting. Like many shale-hosted exhalative deposits, Howards Pass has a fine-grained mineralization that requires long grinding times and large mills. In addition, the mineralization is graphite-rich, which harms recoveries in conventional flotation. Copper Ridge hopes to overcome these difficulties by producing bulk zinc, lead, cadmium, and silver concentrate in a mill circuit, comprising gyratory crushing, semiautogenous grinding, and flotation. Concentrates would be transported south by a slurry pipeline to a pressure leaching, purification, and electrowinning plant at the Robert Campbell Highway, near Frances Lake, or possibly Watson Lake. Annual production is estimated at 350,000 t to 500,000 t of zinc metal, depending on the grade of ore mined (Northern Miner, 2000b).

China.—London-based Billiton plc, formed an "Incorporated Contractual Joint Venture" (ICJV) with Chinese Lanping Nonferrous Metals Co. (LNMC) to develop the Lanping zinc deposit in China. Billiton, through its wholly owned Billiton China BV, eventually will hold 65% of the ICJV. LNMC, is 51%-owned by Yunnan Metallurgy Group, which is wholly owned by the provincial government. Thus, the agreement represented the first commercial joint venture between the Chinese provincial government and an international mining company in which a foreign company has taken a majority stake in a mineral project in China. The Lanping deposit is in Yunnan Province, western China, near the border with Burma. It is described as one of the world's largest undeveloped zinc mineralization, measuring 200 Mt at a grade in excess of 10% zinc. A feasibility study should be completed at the end of 2001. The project could involve a capital investment of about $500 million. When developed, the Lanping facility is expected to produce between 250,000 t and 270,000 t of zinc metal per year (Mining Journal, 2000d).

Congo.—Zinc Corp. of South Africa (Zincor) restated its interest to exercise its option to join America Mineral Fields International Inc. (AMFI) in redevelopment of the historic Kipushi Mine in Congo (Kinshasa). Zincor can earn up to a 50% interest in the proposed joint venture by matching AMFI's expenditures on the project. The joint venture will include a formal agreement with La Générale des Carrières et des Mines, the Congolese mining corporation that owns the Kipushi Mine. The agreement will cover equity ownership, project finance, and dividend distribution. Pending the outcome of a feasibility study and approval by the board of directors, the project could commence once the Congolese Government grants approval. The Kipushi Mine operated from 1925 until 1993, when it was placed on care and maintenance. The mine has measured and indicated resources of 17 Mt grading 16.7% zinc and 2.32% copper. Zincor is a wholly owned subsidiary of Iscor Ltd., the South African iron, steel, and mining group (American Metal Market, 2000d). With minimal initial expenditure, the Kipushi Mine could produce as much as 30,000 t/yr of contained zinc in concentrate, beginning in the first half of 2001. Concentrate would be transported by rail for processing at Zincor's 115,000 t/yr zinc refinery at Springs, South Africa, near Johannesburg (Platt's Metals Week, 2000h).

Ireland.—In 2000, Tara Mines Ltd., subsidiary of Finnish base metal producer Outokumpu Oy, had to resolve two strikes at its Tara Mine at Navan, northwest of Dublin. After a 7-month-long labor dispute, the first strike ended in February, with a Government brokered deal that included an agreement on miners' bonuses and pay, extended shift schedules with increased shift premium payments, and the use of contract workers. Because of the vagueness of the agreement concerning contract workers, a new 2-week strike erupted in November. The new agreement provided for a new training program for 60 workers at the mine and allowed for the interim use of contract workers until the end of August 2001 (Platt's Metals Week, 2000i). Following the successful resolution of the first strike, Outokumpu Oy of Finland approved a mine-life extension of its Tara Mine. At the annual production level of 200,000 t of concentrate, the $43 million extension will add at least 8 years to Tara's mine life. Production from the new southwest extension, measuring 10 Mt and averaging 9% zinc and 2% lead, should start in 2001, and it is anticipated that full capacity will be achieved by 2004 (Mining Journal, 2000i).

The Galmoy zinc-lead mine in County Kilkenny, owned by Arcon International Resources plc, has begun using a three-stage flotation process that reduced by 75% the amount of material that had to be put back through the regrind circuit. Arcon also has doubled the capacity of its acid leach process,

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reducing the magnesium content of the concentrate to 0.44% MgO and improved recoveries to about 87%. The original reserve had been increased through exploration from 6 Mt to 8 Mt grading 11.5% zinc and 1% lead (Metal Bulletin, 2000e).

By the second half of 2000, the Lisheen zinc-lead mine reached full production capacity of 330,000 t/yr of zinc and 40,000 t/yr of lead in concentrate. The mine, 160 km southwest of Dublin in County Tipperary, is jointly owned by Ivernia West plc and Minorco SA (Platt's Metals Week, 2000d). The Lisheen Mine is the third largest zinc mine in Ireland, following Tara and Galmoy. By yearend 2000, these mines reached a combined annual production of about 700,000 t of zinc concentrate, making Ireland one of the world's major zinc producers. Lisheen's proven reserves of 18.9 Mt grading 12.8% zinc and 2.2% lead are in 3- to 7-m-thick seams in two adjacent ore bodies: Main and Derryville. Concentrates, which are described as low in iron with normal levels of cadmium, cobalt, and nickel, are trucked 110 km to Cork where sheds and shiploading facilities have been leased (Metal Bulletin Monthly, 2000).

Kazakhstan.—According to CRU International Ltd. (2000a), the zinc industry of Kazakhstan continues to expand. The expansion of Kaztsink's Maleevsk Mine was completed in July at a cost of $65 million. Increased production at the Maleevsk Mine has offset the closure of the Zyryanovsk Mine. Reserves at Maleevsk are estimated at 36.7 Mt grading 7.7% zinc, 2.6% copper, 1.2% lead, and some gold and silver. An additional contribution will come from the Tishin Mine, where an investment of $6 million should raise production to 1.4 Mt of ore in 2001 (CRU International Ltd., 2000b). Kaztsink's self-sufficiency increased to 71% in 2000 from 54% in 1999; complete self-sufficiency should be achieved by 2001. Slab zinc production in 2000 increased to 262,570 t. At Leninogorsk, which produced about 40% of the company's slab zinc in 2000, Kaztsink proposed to expand capacity by 20% through various new investments. It also planned to increase output at its Ust-Kemenogorsk smelter from 144,200 t/yr in 2000 to 156,000 t/yr in 2001 (CRU International Ltd., 2001).

The biggest contribution to the expanding zinc industry is to come from the Shaimerden oxide-silicate deposit in the Kustanai region of Kazakhstan. The Irish company, Ennex International Ltd., through its subsidiary Zinc Corp of Kazakhstan owns 95% of the project and already concluded a feasibility study. The operation, which will be technically similar to that of Skorpion in Namibia, is to produce 100,000 t/yr of zinc metal over a 6 to 10 year period. Resources are 4.3 Mt grading 21% zinc. The cost of development is estimated to be about $250 million and should result in an exceptionally low operating cost of about 21 cents per pound (Roskill, 2001, p. 115).

Mexico.—During 2000, Industrias Peñoles S.A. de C.V. twice increased the capacity of its Torreón metallurgical complex: early in the year it went from 130,000 t/yr to 160,000 t/yr, and in December it increased to 220,000 t/yr because of increased domestic demand, mainly for zinc alloys due to growth in the construction and automobile sectors (Metal Bulletin, 2000m). Additional zinc concentrate for this expanding production came from increased output at existing mines and, later, two new mines: the Rey de Plata and the Francisco I. Madero. In early October, Mexico's Industrias Peñoles S.A. de C.V. opened its new zinc mine in the coastal state of Guerrero, potentially raising its annual zinc production by 12%. The Rey de Plata Mine is expected to produce 20,000 t/yr of zinc in concentrate by 2001, making it the fifth largest zinc mine in Mexico. The mine is owned 51% by Peñoles, 39% by Dowa Mining Co. Ltd. of Japan, and 10% by Sumitomo Corp., a major Japanese trading company. The Rey de Plata Mine, in Tehuixtla, will create 465 new jobs directly and about 1,000 indirect employment opportunities (American Metal Market, 2000c). The Francisco I. Madero Mine is to produce 96,000 t/yr of zinc concentrate by 2001 (Platt's Metals Week, 2000g).

Namibia.—Anglo American plc is to spend $454 million developing the Skorpion zinc mine and refinery in southern Namibia. The Skorpion Mine is expected to produce about 150,000 t/yr of zinc in concentrate by 2003 over a mine life of at least 15 years. The Skorpion deposit contains reserves of 21.4 Mt grading 10.6% zinc, minable by conventional open pit method. The ore is unusual in that it consists mainly of zinc silicates and zinc carbonates, rather than the more typical zinc sulfide (sphalerite). Accordingly, a special metallurgical process has been developed, consisting of a direct acid leaching of the ore, solid-liquid separation, solvent extraction, and electrowinning to produce special high-grade zinc. When at full capacity, the cost of production should be around $0.20 and $0.23 per pound, making Skorpion one of the lowest cost producers in the world (Miningweb, September 7, 2000, Anglo gives green light to $454 million zinc venture, accessed September 7, 2000, at URL http://www.mips1.net/422567CB004ED3BF/(UNID)/DMKY-4NXM9G).

Peru.—Rio Algom of Canada, Ltd. agreed to a friendly takeover by Billiton plc on August 25. The main incentive for the purchase lies in Rio Algom's 33.75% share in the Antamina copper-zinc project in Peru. The project is already 52% complete and engineering work is 95% finished. Annual production in the first 10 years is expected to be 270,000 t of copper and 160,000 t of zinc (Mining Journal, 2000c). The massive Antamina copper-zinc deposit in Peru is larger than previously believed. Based on new drill results, combined proven and probable reserves increased in volume by 13%, in addition to slightly higher zinc and silver grades. Proven reserves now stand at 313 Mt grading 1.3% copper, 1.06% zinc, 0.03% molybdenum, and 14.13 g/t silver. Probable reserves amount to 246 Mt grading 1.15% copper, 0.99% zinc, 0.028% molybdenum, and 13.71 g/t silver. Antamina is operated by Compañía Minera Antamina, which is now owned by Noranda Inc. (33.75%), Billiton plc (33.75%), Teck Corp. (22.5%), and Mitsubishi Corp. (10%). The project is slated to become the world's third largest zinc producer. Construction is on schedule for full production to begin in late 2001 (Northern Miner, 2000e).

Compañía Minera Volcán S.A., presently Peru's largest privately owned zinc producer, added about 30,000 t of high-grade zinc concentrate to its current production by purchasing the neighboring Chungar and Vinchos Mines for $24 million. The purchase also included the supply of hydroelectric generating capacity, 382 hectare (ha) of land from the majority owners of the Chungar Mine, and 5,700 ha of exploration property from the owners of the Vinchos Mine. The latter property is near Volcán's Paragsha Mine. Over the past 3 years, Volcán has risen from relative obscurity to the largest zinc producer in Peru by purchasing the Mahr Tunel Mine from the

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Government and later buying the Paragsha (formerly Cerro de Pasco) Mine from Centromin (Empresa Minera del Centro del Peru S.A.) (Metal Bulletin, 2000n). Volcán is also planning a $70 million investment over the next 5 years to increase production at its recently purchased Paragsha Mine (Metal Bulletin, 2000k).

Portugal.—Canadian zinc producer EuroZinc Mining Corp. received the final feasibility study for the Aljustrel polymetallic project in southern Portugal in June 2000. The study called for an underground operation producing about 1.6 Mt of ore, with potential for an increase to 2 Mt. The mine was expected to produce 65,800 t of zinc 15,400 t of lead, and 34 t/yr of silver during the first 9 years and 13,600 t/yr of copper in the following 2 years. Aljustrel was estimated to contain proven and probable reserves of 13.8 Mt grading 5.3% zinc, 1.77% lead, 0.26% copper, and 63 g/t silver. EuroZinc received a $32 million incentive package from the Portugese Government towards the $75 million that will be required for the development of the mine. A smaller part of the financing will be used for restarting the production at the Moinho Mine where underground infrastructure is in excellent condition. The proceeds from Moinho production will be used to supplement financing for the Feitais deposit, development of which will take about 2 years. The mine was closed in mid-1999 because of low zinc prices and inefficient mining and milling methods. Recent discoveries and modifications to the milling process should enable profitable mining when the mine is scheduled to reopen in 2001. EuroZinc will earn up to 75% interest from the Government-owned Empresa de Desenvolvimento de Miniero mining company by advancing the project to the production stage (Mining Journal, 2000a).

South Africa.—In September 2000, the board of directors of Anglo American plc approved the development of its Skorpion (Namibia) and Gamsberg (South Africa) zinc projects. The Gamsberg project is expected to produce 300,000 t/yr of refined zinc from 6 Mt/yr of ore containing 6% zinc (Platt's Metals Week, 2000a). Construction may begin in January 2001 and is expected to be completed within 3 years. The Gamsberg Mine project, near Aggeneys in the Northern Cape, will contain an open pit mine 4.5 km^2 and 540 m deep. The mining site will also include a concentrator, two waste rock dumps, and one tailings dam (Metal Bulletin, 2000f).

Spain.—The future of Boliden Ltd.'s Los Frailes zinc mine is in doubt after the Canadian company has decided not to develop pit #3, although it will proceed with developing pit #2. The development of pit #3 would involve stripping back overburden at an additional cost of $26 million, before any revenues are generated from pit #2. Because Boliden does not have the financial resources nor the ability to borrow the necessary funds, its Spanish subsidiary, Boliden Apirsa S.L., has filed a Spanish equivalent of Chapter 11 bankruptcy protection. It would allow Apirsa to preserve assets, pay creditors, and ensure that operations at Los Frailes will continue until the completion of pit #2, planned for October 2001. Apirsa has been incurring significant financial losses since resumption of operations in 1999 after a rupture in the mine's tailings dam (Metal Bulletin, 2000d).

Navan Mining plc (formerly Navan Resources plc) of the United Kingdom has more than doubled its zinc production at its new Aguas Teñidas Mine. By the end of 2000, production rate reached 600,000 t/yr of zinc ore grading 8.7%. During the year, existence of a westward extension of resource was discovered, increasing the overall resource by 10% to 15%, and probably extending the life of the mine beyond the anticipated 15 years. Crushed ore is transported 28 km by road to the Almagrera processing plant (Metal Bulletin, 2000g).

Thailand.—Union Minière SA of Belgium has purchased a 33% interest in Thai zinc producer Padaeng Industry Co. Ltd. The infusion of investment helped Tak smelter, Thailand's sole zinc smelter, to expand production to 101,000 t/yr in 2000 from 95,400 t/yr in 1999. Nearly three-fourths of production was sold on the domestic market; the remaining one-quarter was exported. Domestic consumption of zinc is expected to grow by 5.6% in 2001 and by about 30% in the next few years (Metal Bulletin, 2000h).

In mid-2000, Padaeng signed an agreement on zinc mining and processing with the Government of Laos, covering a 12 km^2 area near Kaiso, north of Vientiane, Laos. Ore from the planned mine will be blended with silicate ore from Padaeng's Mae Sod Mine in Thailand, to produce an even higher quality concentrate for its 106,000-t Tak smelter (Metal Bulletin, 2000i).

Outlook

According to the CEO of Cominco, the zinc industry is ripe for a wave of consolidation comparable to aluminum and copper industries during the past 2 years. The main benefit of mergers would be the ability of a small number of producers to manage resources and capital more effectively, avoiding wasteful investment in unprofitable projects. Even this consolidation may not be enough to improve the low profitability of the zinc industry, which earned a 0.7% return on equity between 1990 and 1999, compared with a 10.3% return for copper producers. Zinc metal prices have been falling 2.3% in real terms for the past 30 years (Platts Metals Week, 2001). Zinc prices most likely will continue to decline in 2001 because zinc production is forecast to increase by 4.6% to 9.34 Mt, while consumption is expected to increase by only 0.2% to 8.83 Mt (Metal Bulletin, 2001).

In contrast to other base metals, there is virtually no mine-site smelting of zinc concentrates, and the volume of zinc concentrates moving either within or across borders is large. Asia and Europe accounted for 72% of world zinc metal production and only 41% of mine production in 2000. America and Australia, on the other hand, accounted for 56% of world mine production and only 26% of metal production in 2000. Although there was significant integration of zinc mining and smelting within a few large companies in the past, it did not increase in the late 20th century. This pattern could begin to change with construction of Skorpion and Shaimerden mining and refining complexes in Namibia and Kazakhstan, respectively.

References Cited

American Metal Market, 2000a, Noranda site proves zinc rich: American Metal Market, v. 108, no. 79, April 25, p. 8.
———2000b, Pasminco ramps up output at one mine, winds down other: American Metal Market, v. 108, no. 36, February 24, p. 6.
———2000c, Peñoles expects big boost from new mine: American Metal Market, v. 108, no. 197, October 12, p. 2.
———2000d, Zincor intends to participate in DRC project: American Metal

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Market, v. 108, no. 243, December 19, p. 7.
ASARCO Inc. News, 2000, Grupo Mexico forms new mining and operations subsidiary: ASARCO Inc. News, December 28.
Cominco Ltd., 2001, Annual report—2000: Vancouver, BC, Canada, Cominco Ltd., 55 p.
Cominco News, 2001, Cominco reports $170 million ($1.99 per share) of net earnings for 2000: Cominco News, January 23, p. 30.
CRU International Ltd., 2000a, Kaztsink commissions Maleevsk: CIS Metals Review, third quarter 2000, p. 7.
———2000b, New zinc smelter at Balkhash: CIS metals review, First Quarter 2000, p. 5.
———2000c, Production news: CRU Monitor, May 2000, p. 7.
———2001, Kaztsink moves ahead: CIS Metals Review, first quarter 2001, p. 7.
International Lead and Zinc Study Group, 2001a, Table 31—Refined zinc—Metal consumption: Lead and Zinc Statistics, v. 41, no. 6, p. 41.
———2001b, Table 37—Zinc—Western World—Metal stocks—Current trends: Lead and Zinc Statistics, v. 41, no. 6, p. 51.
———2001c, Table 39—Zinc—Trade with Eastern countries: Lead and Zinc Statistics, v. 41, no. 6, p. 43.
Metal Bulletin, 2000a, Billiton signs deal at Canadian zinc deposit: Metal Bulletin, no. 8510, September 21, p. 7.
———2000b, Breakwater continues mine expansion: Metal Bulletin, no. 8476, May 18, p. 7.
———2000c, Breakwater to halt operations at Langlois mine: Metal Bulletin, no. 8531, December 4, p. 5.
———2000d, Future of Los Frailes Zn mine threatened: Metal Bulletin, no. 8514, October 5, p. 5.
———2000e, Galmoy fine tunes to cut cost, improve product: Metal Bulletin, no. 8478, May 25, p. 5.
———2000f, Gamsberg zinc project awaits green light: Metal Bulletin, no. 8480, June 1, p. 9.
———2000g, Navan increases Spanish zinc production: Metal Bulletin, no. 8518, October 19, p. 7.
———2000h, Padaeng plans smelter expansion: Metal Bulletin, no. 8486, June 22, p. 5.
———2000i, Padaeng's Laos mine to supply Thai smelter: Metal Bulletin, no. 8493, July 17, p. 6.
———2000j, Paraibuna aims to double zinc production: Metal Bulletin, no. 8459, March 16, p. 7.
———2000k, Peru's Volcan prepares for expansion: Metal Bulletin, no. 8486, June 22, p. 8.
———2000l, Sun Metals looks at boosting Townsville production in 2001: Metal Bulletin, no. 8511, September 25, p. 9.
———2000m, Torreón capacity ramp-up completed: Metal Bulletin, no. 8535, December 18, p. 5.
———2000n, Volcan buys Chungar and Vinchos Zn mines: Metal Bulletin, no. 8509, September 18, p. 10.
———2000o, Western Metals to expand Pillara plant and close Cadjebut: Metal Bulletin, no. 8452, February 21, p. 6.
———2001, Zinc prices to remain depressed: Metal Bulletin, no. 8571, May 3, p. 7.
Metal Bulletin Monthly, 2000, Lisheen begins to deliver: Metal Bulletin Monthly, no. 349, January, p. 46-49.
Mining Engineering, 2000, Expansion would make Kidd Creek world's deepest base metal mine: Mining Engineering, v. 52, no. 9, September, p. 29.
Mining Journal, 2000a, Aljustrel feasibility positive: Mining Journal, v. 334, no. 8588, June 23, p. 487.
———2000b, Bell-Allard suspension: Mining Journal, v. 334, no. 8572, March 3, p. 178.
———2000c, Billiton agrees terms with Rio Algom: Mining Journal, v. 335, no. 8598, September 1, p. 179.
———2000d, Billiton commits to Lanping: Mining Journal, v. 334, no. 8586, June 9, p. 1.
———2000e, George Fisher update: Mining Journal, v. 335, no. 8593, July 28, p. 64.
———2000f, Gunman phase three complete: Mining Journal, v. 335, no. 8611, December 1, p. 433.
———2000g, Kagara gains more ground: Mining Journal, v. 335, no. 8602, September 29, p. 254.
———2000h, Mine costs rise for zinc: Mining Journal, v. 335, no. 8612, December 8, p. 447.
———2000i, Outokumpu approves Tara extension: Mining Journal, v. 334, no. 8580, April 28, p. 330.
———2001, Doctor Mine exploration results confirm zinc zone: Mining Journal, v. 336, no. 8616, January 12, p. 27.
Northern Miner, 2000a, Cominco flashes green light for Pend Oreille: Northern Miner, v. 86, no. 30, September 18, p. 1-2.
———2000b, Copper Ridge: Northern Miner, v. 86, no. 36, October 30, p. 11, 13.
———2000c, Expatriate acts alone at Kudz Ze Kayah: Northern Miner, v. 86, no. 12, May 15, p. 3, 10.
———2000d, Finlayson: Northern Miner, v. 86, no. 39, November 20, p. 1-2.
———2000e, Partners expand Antamina: Northern Miner, v. 86, no. 41, December 4-10, p. 1-2.
Platt's Metals Week, 2000a, Anglo to OK Gamsberg, Skorpion projects: Platt's Metals Week, v. 71, no. 28, July 10, p. 15.
———2000b, Cambior sells Quebec zinc assets to Breakwater: Platt's Metals Week, v. 71, no. 12, March 20, p. 2-3.
———2000c, Cominco to increase Red Dog zinc output: Platt's Metals Week, v. 71, no. 7, February 14, p. 14.
———2000d, Lisheen to reach capacity in H2: Platt's Metals Week, v. 71, no. 13, March 27, p. 10.
———2000e, Pasminco formally opens Century zinc: Platt's Metals Week, v. 71, no. 15, April 10, p. 13.
———2000f, Pend Oreille revival: Platt's Metals Week, v. 71, no. 37, September 11, p. 9.
———2000g, Peñoles expanding Torreón zinc output: Platt's Metals Week, v. 71, no. 6, February 7, p. 7.
———2000h, South Africa's Zincor looks to develop Kipushi zinc mine: Platt's Metals Week, v. 71, no. 33, August 14, p. 1.
———2000i, Tara zinc strike ends; expansion on track: Platt's Metals Week, v. 71, no. 50, December 11, p. 2.
Platts Metals Week, 2001, AZA meeting highlights zinc industry: Platts Metals Week, v. 72, no. 7, February 12, p. 6.
Roskill Information Services Ltd., 2001, The economics of zinc: Roskill Information Services Ltd., London, 248 p.
U.S. Geological Survey, 1998, 1998 Assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.
U.S. Embassy, Canberra, Australia, 2000, Australia's mineral sector outlook improves: U.S. Department of State Telegram, ZCZCOIO9951, July, 5 p.
U.S. Environment Protection Agency, 2000, Hazardous waste management system; identification and listing of hazardous waste; final exclusion: Federal Register, v. 65, no. 10, January 14, p. 21651-21657.
Wedow, H., Jr., Kiilsgaard, T.H., Heyl, A.V., and Hall, R.B., 1973, Zinc, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 697-711.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Zinc. Ch. in Mineral Commodity Summaries, annual.
Zinc. Ch. in Minerals Yearbook, annual.
Zinc. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Zinc. Mineral Industry Surveys, monthly.

Other Sources

Engineering and Mining Journal, monthly.
International California Mining Journal, monthly.
Ryan's Notes, weekly.
U.S. Zinc Industry—A History, Statistics, and Glossary. Jolly, J.H., 1997, Baltimore, American Literary Press, Inc.
Zinc. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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TABLE 1
SALIENT ZINC STATISTICS 1/

(Metric tons, unless otherwise specified)

		1996	1997	1998	1999	2000
United States:						
Production:						
Domestic ores, contained zinc		628,000	632,000	755,000	813,000 r/	829,000
Domestic ores, recoverable zinc		586,000	592,000	709,000	771,000 r/	786,000
Value, recoverable zinc	thousands	$660,000 r/	$843,000 r/	$804,000 r/	$909,000 r/	$1,020,000
Refined zinc:						
From domestic ores		214,000	195,000	192,000	180,000	137,000
From foreign ores		11,400	31,700	41,900	61,100	90,900
From scrap		140,000	140,000	134,000	131,000	143,000
Total		366,000	367,000 r/	368,000	371,000	371,000
Secondary zinc 2/		238,000	234,000	292,000	267,000	290,000
Exports:						
Ores and concentrates (zinc ocntent)		425,000	461,000	552,000	531,000	523,000
Slab zinc		1,970	3,630	2,330	1,880	2,770
Rolled zinc		5,020	9,110	9,920	3,870	3,530
Imports for consumption:						
Ores and concentrates (zinc ocntent)		15,100	49,600	46,300	74,600	52,800
Refined (slab) zinc		827,000	876,000	879,000	966,000	915,000
Rolled zinc		16,900	19,200	16,900	22,600	9,380
Stocks of slab zinc, December 31:						
Producer		11,100	9,360	9,060	9,960	7,890
Consumer		59,700	60,400	45,400	64,400	58,300
Merchant		4,800	18,500	13,300	9,690	10,500
Total		75,600	88,200	67,700	84,100	76,600
Government stockpile		258,000 r/	225,000	199,000	177,000	138,000
Consumption:						
Refined zinc:						
Reported		788,000	672,000	647,000	614,000	640,000
Apparent 3/		1,210,000	1,260,000	1,290,000	1,340,000	1,330,000
All classes 4/		1,450,000	1,490,000	1,580,000	1,610,000	1,620,000
Price, special high grade	cents per pound	51.11	64.56	51.43	53.48	55.61
World:						
Production:						
Mine	thousand metric tons	7,480	7,530 r/	7,690 r/	8,040	8,730 e/
Smelter	do.	7,610 r/	7,920 r/	8,160 r/	8,570 r/	9,050 e/
Price, London Metal Exchange	cents per pound	46.50	59.70	46.45	48.80	51.15

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

2/ Zinc in metal products and compounds derived directly from scrap; refined secondary zinc is listed separately in the table.

3/ Domestic production plus net imports, plus or minus stock changes.

4/ Apparent consumption of refined zinc plus reported consumption of zinc in metal products and compounds derived directly from ore, concentrate, or scrap.

TABLE 2
MINE PRODUCTION OF RECOVERABLE ZINC IN THE UNITED STATES, BY STATE 1/

(Metric tons)

State	1999	2000
Alaska 2/	563,000	574,000
Missouri	48,700	51,800
Montana	22,200	16,600
Other 3/	137,000 r/	143,000
Total	771,000 r/	786,000

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Data based, in part, on publicly available information.

3/ Includes production from Idaho, New York, and Tennessee.

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TABLE 3
LEADING ZINC PRODUCING MINES IN THE UNITED STATES IN 2000, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of zinc
1	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Lead-zinc ore.
2	Greens Creek 1/	Juneau, AK	Kennecott Greens Creek Mining Co.	Zinc ore.
3	Balmat	St. Lawrence, NY	Zinc Corp. of America	Do.
4	Gordonsville	Smith, TN	Pasminco Ltd.	Do.
5	Young	Jefferson, TN	ASARCO Inc.	Do.
6	Montana Tunnels	Jefferson, MT	Apollo Gold Co.	Do.
7	Brushy Creek	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
8	Pierrepont	St. Lawrence, NY	Zinc Corp. of America	Zinc ore.
9	Immel	Knox, TN	ASARCO Inc.	Do.
10	Buick	Iron, MO	Doe Run Resources Corp.	Lead ore.
11	West Fork	Reynolds, MO	do.	Do.
12	Casteel	Iron, MO	do.	Do.
13	Cumberland	Smith, TN	Pasminco Ltd.	Zinc ore.
14	Coy	Jefferson, TN	ASARCO Inc.	Do.
15	Fletcher	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
16	Clinch Valley	Grainger, TN	Pasminco Ltd.	Zinc ore.

1/ Updated to reflect locality name change.

TABLE 4
REFINED ZINC PRODUCED IN THE UNITED STATES 1/

(Metric tons)

	1999	2000
Primary:		
From domestic ores	180,000	137,000
From foreign ores	61,100	90,900
Total	241,000	228,000
Secondary	131,000	143,000
Grand total (excludes zinc recovered by remelting)	371,000	371,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 5
REFINED ZINC PRODUCED IN THE UNITED STATES, BY GRADE 1/

(Metric tons)

Grade	1999	2000
Special High	93,400	82,200
Continuous Galvanizing	103,000	93,200
Other 2/	175,000	195,000
Total	371,000	371,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes Controlled Lead, High, and Prime Western grades.

TABLE 6
SLAB ZINC CAPACITY OF PRIMARY ZINC PLANTS IN THE UNITED STATES, BY TYPE OF PLANT AND COMPANY

(Metric tons)

Type of plant and company	1999	2000
Electrolytic:		
Big River Zinc Corp., Sauget, IL	95,000	100,000
Pasminco Ltd. Clarksville, TN	115,000	115,000
Electrothermic:		
Zinc Corporation of America, Monaca, PA 1/	155,000	155,000
Total	365,000	370,000

1/ Includes secondary capacity.

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TABLE 7
STOCKS AND CONSUMPTION OF NEW AND OLD ZINC SCRAP IN THE UNITED STATES IN 2000, BY TYPE OF SCRAP 1/

(Metric tons, zinc content)

Type of scrap	Stocks, January 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, December 31
Diecastings	W	W	--	W	W	191
Flue dust	756	W	W	W	W	187
Galvanizer's dross	2,830	41,000	41,000	--	41,000	2,830
Old zinc 2/	72	305	--	308	308	69
Remelt die-cast slab	W	W	--	W	W	38
Remelt zinc 3/	177	W	W	--	W	744
Skimmings and ashes 4/	413	27,500	27,100	--	27,100	810
Other 5/	1,040 r/	161,000	104,000	58,200	162,000	133
Total	5,290 r/	230,000	172,000	58,500	230,000	5,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes engraver's plates and rod and die scrap.
3/ Includes new clippings.
4/ Includes sal and die-cast skimmings.
5/ Includes chemical residues and solutions, electrogalvanizing anodes, fragmentized diecastings, and steelmaking dust.

TABLE 8
PRODUCTION OF ZINC PRODUCTS FROM ZINC-BASE SCRAP
IN THE UNITED STATES 1/

(Metric tons)

Products	1999	2000
Redistilled slab zinc	131,000	143,000
Other zinc metal products 2/	4,950	5,130
Zinc in chemical products	94,300	63,500
Zinc dust	3,010	3,770

1/ Data are rounded to no more than three significant digits.
2/ Includes electrogalvanizing anodes, remelt die-cast slab, and other metal alloys.

TABLE 9
ZINC RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY TYPE OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
Type of scrap:		
New scrap:		
Zinc-base	128,000	167,000
Copper-base	192,000	201,000
Magnesium-base	428 r/	430 e/
Total	321,000	369,000
Old scrap:		
Zinc-base	62,300	56,100
Copper-base	14,800 r/	9,850
Aluminum-base	696 r/	630
Magnesium-base	304 r/	300 e/
Total	78,100 r/	66,900
Grand total	399,000 r/	436,000
Form of recovery:		
Metal:		
Slab zinc	131,000	143,000
Zinc dust	3,010	3,770
Total	134,000	146,000

See footnotes at end of table.

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TABLE 9--Continued
ZINC RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
Form of recovery--Continued:		
In brass and bronze	165,000 r/	233,000
In chemical products:		
Zinc oxide (lead free)	35,900	23,100
Zinc sulfate	34,400	32,800
Zinc chloride	W	W
Miscellaneous 2/	29,600	13,800
Total	265,000 r/	302,000
Grand total	399,000 r/	449,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes electrogalvanizing anodes and zinc content of slab made from remelt die-cast slab.

TABLE 10
U.S. CONSUMPTION OF ZINC 1/

(Metric tons)

	1999	2000
Refined zinc, apparent	1,340,000	1,330,000
Ores and concentrates (zinc content)	986	225
Secondary (zinc content) 2/	267,000	290,000
Total	1,610,000	1,620,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes secondary slab zinc and remelt zinc.

TABLE 11
U.S REPORTED CONSUMPTION OF ZINC IN 2000, BY INDUSTRY USE AND GRADE 1/

(Metric tons)

Industry use	Special high grade	High grade	Prime Western	Remelt and other grades	Total
Galvanizing	116,000	35,400	101,000	41,300	293,000
Zinc-base alloys	117,000	W	W	W	123,000
Brass and bronze	41,700	W	23,500	W	82,800
Other	57,200	25,200	82,400	231	XX
Total	332,000	60,600	206,000	41,500	640,000

W Withheld to avoid disclosing company proprietary data; included with "Other" and in "Total."
XX Not applicable.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 12
ZINC CONTAINED IN PIGMENTS AND COMPOUNDS PRODUCED AND SHIPPED IN THE UNITED STATES 1/ 2/

(Metric tons)

	1999		2000	
	Production	Shipments	Production	Shipments
Zinc oxide	114,000	116,000	102,000	101,000
Zinc sulfate	35,400	33,700	33,000	38,700

1/ Excludes leaded zinc oxide, lithopone, and zinc chloride.
2/ Data are rounded to no more than three significant digits.

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TABLE 13
REPORTED SHIPMENTS OF ZINC CONTAINED IN ZINC OXIDE, BY INDUSTRY 1/ 2/

(Metric tons)

	1999	2000
Ceramics	5,100	4,320
Chemicals	23,300	20,200
Paints	5,610	4,600
Rubber	76,600	67,500
Other 3/	5,020	4,790
Total	116,000	101,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ In addition, zinc contained in zinc oxide was imported as follows: 1999--65,203 and 2000--71,013; distribution cannot be distinguished by industry.
3/ Includes agriculture and photocopying.

TABLE 14
U.S. EXPORTS OF ZINC ORES AND CONCENTRATES, BY COUNTRY 1/

	1999		2000	
	Quantity (metric tons, zinc content)	Value (thousands)	Quantity (metric tons, zinc content)	Value (thousands)
Australia	24,400	$10,800	24,400	$11,000
Belgium	219,000	96,100	202,000	97,000
Canada	61,000	83,400	49,900	65,700
Germany	32,700	14,600	28,100	14,700
Italy	1,300	1,250	6,840	2,990
Japan	123,000	69,300	108,000	51,500
Korea, Republic of	51,000	23,900	73,900	37,100
Mexico	5,080	2,160	1,990	1,070
Netherlands	7 r/	8 r/	--	--
Saudi Arabia	28	46	68	139
Spain	76	43	--	--
United Kingdom	14,100	14,700	28,400	16,400
Other	46 r/	140 r/	155	269
Total	531,000	317,000	523,000	298,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 15
U.S. EXPORTS OF ZINC COMPOUNDS 1/

	1999		2000	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Zinc chloride	3,200	$2,140	3,290	$2,440
Zinc compounds, n.s.p.f.	864	3,280	5,240	17,600
Zinc oxide	7,260	11,700	7,080	12,400
Zinc sulfate	4,750	2,940	6,950	22,800

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF ZINC COMPOUNDS 1/

	1999		2000	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Lithopone	1,180	$1,070	1,380	$1,150
Zinc chloride	1,650	1,520	1,110	1,240
Zinc compounds, n.s.p.f.	34	32	19	21
Zinc hydrosulfite	100	239	174	361
Zinc oxide	65,200	66,600	71,000	74,200
Zinc sulfate	10,500	6,350	13,700	6,800

1/ Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

TABLE 17
ZINC: WORLD MINE PRODUCTION (ZINC CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria	5,912	3,960	25,465 r/	42,306 r/	38,303 3/
Argentina	31,093	33,357	35,560	34,195 r/	35,000
Australia	1,071,000	1,036,000	1,059,000	1,163,000	1,420,000 3/
Bolivia	145,092	154,491	152,110	146,316 r/	150,000
Bosnia and Herzegovina e/	300	300	300	300	300
Brazil	117,343	152,636	87,474	96,500	96,500
Bulgaria e/	19,800 3/	20,000	17,000	11,000 r/	11,000
Burma	572	467	474	279	220
Canada	1,222,388	1,076,385	1,061,645	963,321 r/	935,686 p/
Chile	36,004	33,934	15,943	32,263	33,000
China	1,120,000 e/	1,200,000 e/	1,273,000	1,476,000 r/	1,710,000
Ecuador e/	100	100	100	100	100
Finland	26,294	30,800	30,700 r/ e/	20,000 r/ e/	16,200 3/
Georgia e/	500	200	200	200	200
Greece	13,602	17,800 e/	29,100	18,900	16,900 3/
Honduras	37,000	39,500	36,639	40,996	41,000
India	148,200	142,000	143,000	145,000 e/	144,000
Iran	76,300	76,500	82,000	80,000 e/	80,000
Ireland	164,168	194,796	182,000	226,000	262,900 3/
Italy	11,055	8,470	2,500 e/	-- e/	--
Japan	79,709	71,569	67,670	64,263 r/	63,547 3/
Kazakhstan	225,000	224,051	224,300	288,300	325,000 3/
Korea, North e/	210,000	210,000	200,000	190,000	190,000
Korea, Republic of	8,384	8,992	10,488 r/	9,832 r/	9,500
Macedonia	15,017	15,800 r/	14,328 r/	8,000 r/ e/	12,200 3/
Mexico	377,599	379,252	395,391	360,000 e/	392,791 3/
Morocco	79,662	89,248	112,000	115,000 e/	130,000
Namibia	35,873	39,658	42,142	34,639 r/	37,800 3/
Norway	8,591 r/	7,900 r/	-- r/	-- r/	--
Peru	760,563	865,267	868,958	899,457	910,303 p/
Poland	159,000	158,300	157,900 r/	155,000 r/ e/	155,000
Romania	32,082	29,366	30,000 e/	26,536 r/	27,455 3/
Russia	126,000	121,000 e/	115,000 e/	132,000	136,000 3/
Saudi Arabia	500 e/	619	3,550 r/	3,161 r/	3,000
Serbia and Montenegro	12,000	13,000	14,000	1,000 r/ e/	2,500
South Africa	76,853	71,062	69,630	69,733	62,703 3/
Spain	140,100	171,800	128,100	110,000	200,000
Sweden	160,325	155,400	164,711	175,000 e/	176,200 3/
Thailand	19,000 r/	15,000 r/	25,000 r/	24,000 r/	21,000
Tunisia	31,920	2,967	31,368	49,066 r/	41,247 3/
Turkey 4/	14,921	11,255 r/	6,000 r/ e/	1,500 r/ e/	1,000
United States	628,000	632,000	755,000	813,000 r/	829,000 3/
Uzbekistan	12,000 e/	-- 5/	-- 5/	-- 5/	-- 5/
Vietnam e/	16,000	16,000 r/	18,000	18,000 r/	16,000
Total	7,480,000	7,530,000 r/	7,690,000 r/	8,040,000	8,730,000

See footnotes at end of table.

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TABLE 17--Continued
ZINC: WORLD MINE PRODUCTION (ZINC CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY 1/ 2/

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 01, 2001.
3/ Reported figure.
4/ Content in ore hoisted.
5/ Mining operations appear to have been sharply curtailed or to have ceased.

TABLE 18
ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Algeria, primary and secondary e/	30,000	29,300	31,000	34,000	34,000
Argentina:					
Primary	36,392	38,672	38,677	40,224 r/	40,000
Secondary e/	2,900	3,100	3,100 3/	3,220 r/ 3/	3,000
Total	39,292	41,772	41,777	43,444 r/	43,000
Australia:					
Primary 4/	326,000	307,000	312,000	338,000	490,000 3/
Secondary e/	4,500	10,000	10,000	10,000	10,000
Total e/	331,000	317,000	322,000	348,000	500,000
Belgium, primary and secondary	234,400	243,600 r/	205,000	232,400	251,700 3/
Brazil:					
Primary	186,339	185,701	176,806 r/	187,010 r/	194,000
Secondary e/	7,000	7,000	7,000	7,000	7,000
Total	193,339	192,701	183,806 r/	194,010 r/	201,000
Bulgaria, primary and secondary	68,018	70,420	72,755	84,000 e/	85,000
Canada, primary	715,553	703,798	745,131	776,927 r/	787,527 p/
China, primary and secondary e/	1,180,000	1,430,000	1,490,000	1,700,000 r/	1,920,000
Czech Republic, secondary e/	1,000	1,000	1,000	1,000	1,000
Finland, primary	176,300	175,300	199,000	225,200	223,000 3/
France, primary and secondary e/	324,300 3/	346,000	321,000	330,000 r/	348,000
Germany, primary and secondary	327,015	251,700	334,000 e/	330,000 e/	325,000
India:					
Primary	143,600	159,000 e/	171,900	175,000 e/	176,000 3/
Secondary e/	24,000	24,000	25,000	25,000	25,000
Total e/	168,000	183,000	197,000	200,000	201,000
Italy, primary and secondary	269,000	227,700	231,600	152,800	168,000
Japan:					
Primary	500,674	500,603	513,916	524,979 r/	541,704 3/
Secondary	141,593	149,605	138,771	158,637 r/	158,806 3/
Total	642,267	650,208	652,687	683,616 r/	700,510 3/
Kazakhstan, primary and secondary	190,000	188,996	240,728 r/	249,327 r/	260,000
Korea, North, primary e/	200,000	200,000	180,000	180,000	180,000
Korea, Republic of, primary	286,526	335,488	390,260	430,108	473,897 3/
Macedonia, primary and secondary e/	38,000	53,000	57,000	48,000 3/	45,000
Mexico, primary	221,736	231,444	230,325	218,913 r/	230,000
Netherlands, primary 5/	207,100	201,100	218,700	220,000 e/	215,000 3/
Norway, primary	134,900	137,400	128,000 e/	132,600 r/	125,800 3/
Peru, primary	173,139	171,691	174,654	196,978 r/	199,813 p/
Poland. primary and secondary	163,100	171,000	175,000 e/	178,000	175,000
Portugal, primary e/	3,600	3,600	3,600	3,600 r/	3,600
Romania, primary and secondary	28,162	30,226	29,427	25,000 e/	25,000
Russia, primary and secondary e/	172,000	189,000	192,000	221,000 r/	230,000
Serbia and Montenegro, primary and secondary	29,954	29,454	14,000 e/	683 r/	8,291 3/
Slovakia, secondary e/	1,000	1,000	1,000	1,000	1,000
Slovenia, primary and secondary e/	2,000	--	--	--	--
South Africa, primary	101,100	108,500	107,400	114,000 e/	115,000
Spain, primary and secondary	360,800	364,200	360,000 e/	375,000 e/	385,000
Thailand, primary	59,738	72,035 r/	75,904	75,639	77,525 3/
Turkey, primary	22,392	37,074	35,716 r/	27,000 e/	25,000

See footnotes at end of table.

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TABLE 18--Continued
ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Ukraine, secondary e/	2,000	2,000	--	--	--
United Kingdom, primary and secondary	96,867	107,704	99,600 r/	132,800 r/	96,600 3/
United States:					
Primary	226,000	226,000	234,000	241,000	228,000 3/
Secondary	140,000	140,000	134,000	131,000	143,000 3/
Total	366,000	367,000	368,000	371,000	371,000 3/
Uzbekistan, primary e/	45,000	53,000	52,000	27,000	18,000
Grand total	7,610,000 r/	7,920,000 r/	8,160,000 r/	8,570,000 r/	9,050,000
Of which:					
Primary	3,770,000 r/	3,850,000 r/	3,990,000 r/	4,130,000 r/	4,340,000
Secondary	324,000	338,000	320,000	337,000 r/	348,000
Undifferentiated	3,520,000	3,740,000	3,850,000	4,100,000	4,360,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Wherever possible, detailed information on raw material source of output (primary--directly from ores, and secondary--from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 1, 2001.

3/ Reported figure.

4/ Excludes zinc dust.

5/ Sales.

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ZIRCONIUM AND HAFNIUM

By James B. Hedrick

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Zirconium is produced from two ore minerals. The principal economic source of zirconium is the zirconium silicate mineral zircon ($ZrSiO_4$). The mineral baddeleyite, a natural form of zirconium oxide or zirconia (ZrO_2), is a distant second to zircon in its economic significance. Zircon is the primary source of all hafnium. Zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. Zircon is a coproduct or byproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile or tin minerals. The major end uses of the mineral zircon are refractories, foundry sands (including investment casting), and ceramic opacification. Zircon is also marketed as a natural gemstone, and its oxide is processed to produce cubic zirconia, a diamond and colored gemstone simulant. Zirconium metal is used in nuclear fuel cladding, chemical piping in corrosive environments, heat exchangers, and various specialty alloys.

The principal uses of hafnium are in nuclear control rods, nickel-based superalloys, nozzles for plasma arc metal cutting, and high-temperature ceramics.

World production of zirconium mineral concentrates was estimated to have increased slightly in 2000. Data on U.S. production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon increased as a heavy-mineral sand mining operation in Virginia continued to improve recovery rates and scale-up production. In 2000, production of milled zircon was essentially unchanged from that of previous years. According to U.S. Census Bureau trade statistics, the United States was a net exporter of zirconium ore and concentrates. U.S. imports of zirconium ore and concentrates increased by 13%, and domestic exports of zirconium ore and concentrates increased by 5% compared with 1999.

With the exception of prices and referenced data, all survey data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Production

Data for zirconium and hafnium materials are developed by the U.S. Geological Survey from one voluntary survey of domestic operations. Of the 47 operations surveyed, 25 responded, and 2 were removed because they no longer used the material. Data for zircon concentrates are developed by a second voluntary survey of domestic operations. The two domestic zircon producers, which have three mining and processing operations, responded. Data for nonrespondents were estimated based on prior year levels. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data.

Domestic production of milled zircon increased slightly and production of zirconium oxide increased by 34% from their

Zirconium and Hafnium in the 20th Century

Just before the turn of the century, zirconium oxide changed the world forever from nights dimly illuminated by candles and oil and gas lamps to the bright glow of incandescent lighting. The incandescent lamp mantle industry was established in 1884 with mantles of zirconium, lanthanum and yttrium oxides. By 1900, the zirconium oxide mantle mixture had been replaced with an improved, brighter oxide mixture of thorium and cerium. That same year, the Nernst lamp, which used rods ("glowers") made of 25% yttrium oxide and 75% zirconium oxide, came into use. In this lamp, it was necessary to heat the glowers with an auxiliary device to about 700° C, at which point it became conductive, and the resistance caused it to glow with a brilliant white incandescence. With the advent of the electric incandescent lamp around 1912, zirconia's use in Nernst glowers declined. Other commercial applications of zirconium oxide in 1900 were in opacification of enamels and enamelware, in paints, and in making x-ray images. The principal use of the zirconium minerals zircon and baddeleyite was in refractory materials. Domestic zircon production at the start of the 20th century was from mines centered around Zirconia, Henderson County, NC. All production was used in the United States.

In 1900, metallic zirconium had no commercial applications, although several uses had been tried or suggested. Ferrozirconium was developed prior to World War I and used as armor plate, bullet-proof metal, and armor-piercing projectiles. In 1930, the pure metal was first used commercially in the United States as a smokeless flashlight (flash powder) in photography, a use patented in Germany 9 years earlier. This use quickly waned with the development of the flash bulb which used only a thin coating of zirconium to ignite lower cost aluminum foil.

In 2000, the United States was a major producer of zircon and zirconium. Zircon was produced at mines in Florida and Virginia and was exported to many countries, the principal destinations being Italy and Mexico, where most of it was used in the opacification of ceramic tile and sanitaryware. To meet demand, zircon was imported from several countries, the principal producing sources being Australia and South Africa. Zirconium metal and alloys were produced in Oregon and Utah. Zirconium's principal uses in 2000 were in nuclear reactor fuel cladding, heat exchangers, and corrosion resistant piping for chemical plants. Zirconium exports were shipped primarily to Canada, Japan, and the United Kingdom. The main sources of U.S. imports of zirconium were France, Germany, Japan, and Canada.

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1999 levels (table 1).

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands containing the titanium minerals ilmenite and rutile. In 2000, U.S. mine producers of zircon were E.I. du Pont de Nemours and Co. (DuPont) and Iluka Resources, Inc. [previously RGC (USA) Mineral Sands, Inc.], a subsidiary of the Australian company Iluka Resources Ltd. DuPont produced zircon from its Highland and Maxville heavy-mineral sands deposits near Starke, FL. Iluka produced zircon from its heavy-mineral sand operations at Green Cove Springs, FL, and Stony Creek, VA. U.S. producers of zirconium and hafnium metal were Wah Chang, an Allegheny Technologies company (prior to January 2000 named Oremet-Wah Chang, a subsidiary of Allegheny-Teledyne Corp.), Albany, OR; and Western Zirconium, a subsidiary of Westinghouse Electric Co., Ogden, UT. Primary zirconium chemicals were produced by Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals were produced by about 10 companies, and zirconia was produced from zircon sand at plants in Alabama, New Hampshire, New York, Ohio, and Oregon.

Iluka continued to improve production output from that of the previous year at its Old Hickory Mine in Stony Creek, VA. The original zircon production capacity at Stony Creek was 30,000 metric tons per year (t/yr). Phase one of a $100 million expansion announced in 1999 by Iluka Resources Ltd. will be at the Old Hickory Mine in Virginia, and phase two, at the Green Cove Springs Mine in Florida (Mineral Sands Report, 2000d). The feasibility study for phase one was completed in 2000.

Altair International Inc. announced that it had broken ground on the construction of a pilot plant at its two heavy-mineral sand deposits near Camden, TN. The deposits contain an estimated 490 million tons (Mt) grading 3.6% heavy minerals. The prime contractor for the site clearing and settling pond construction was Hubbs contractors of Camden. MD Mineral Technologies, which had been previously selected to design and engineer the plant, is expected to oversee the plant construction and startup (Altair International Inc., June 22, 2000, Altair announces groundbreaking at Camden, accessed March 13, 2001, at URL http://www.altairint.com/News/2000/2000.html).

Consumption

Approximately 95% of all zirconium consumed is in the form of zircon, zirconium oxide, or other zirconium chemicals. The remainder is consumed as zirconium metal and zirconium-containing alloys.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds. Zircon in the form of refractory bricks and blocks is used in furnaces and hearths for containing molten metals. Glass tank furnaces use fused cast and bonded alumina-zirconia-silica-base refractories. Baddeleyite is used principally in the manufacture of alumina-zirconia abrasive and in ceramic colors and refractories.

Stabilized zirconium oxide exhibits high light reflectivity and good thermal stability and is primarily used as an opacifier and pigment in glazes and colors for pottery and other ceramic products. Yttria stabilized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in furnaces and automobile engines. YSZ is also used in the manufacture of a diverse array of products including high temperature, high strength structural ceramics, heat- and break-resistant shirt buttons, golf shoe cleats, golf putters, fiber optic connector components, coatings for the hot sections of jet engines, and cubic zirconia, a gemstone simulant for diamonds and colored gemstones.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium is used as cladding for nuclear fuel rods. Commercial grade zirconium, unlike nuclear grade, contains hafnium and is used in the chemical process industries because of its excellent corrosion resistance.

Hafnium is used in nuclear control rods because of its high thermal neutron absorption cross section. However, the largest end use for hafnium metal is as an alloy addition in superalloys.

Prices

In 2000, the increased demand for zircon concentrates resulted in an increase in price. The average value of imported ore and concentrates increased by 27% to $396 per ton in 2000 from $311 per ton in 1999. Domestic prices of standard- and premium-grade zircon increased as a result of a tightening of supply, especially for premium grades. Published prices for imported grades of zircon were higher than those of 1999. Published prices for zirconium, hafnium, and zirconium oxide products were unchanged or slightly higher (table 2).

Foreign Trade

According to U.S. Census Bureau trade statistics, the United States was a net exporter of zirconium ore and concentrates in 2000. U.S. exports of zirconium ore and concentrates were 72,900 metric tons (t), a 5% increase from that of 1999 (table 3). The United States was a net exporter of zirconium and hafnium metal in 2000. U.S. exports of unwrought zirconium metal, waste, and scrap were 180 t, a 15% increase in tonnage compared with those of 1999. U.S. exports classified as "other zirconium metal, waste, and scrap" were 1,030 t, a 22% increase from the 1999 level.

U.S. imports of zirconium ore and concentrates were 65,200 t, an increase of 7,560 t from those of 1999 (table 4). Australia and South Africa supplied about 94% of the imports of ores and concentrates. Imports of unwrought zirconium metal and waste and scrap amounted to 1,040 t, a 22% increase compared with those of 1999. The leading import sources of unwrought zirconium were, in descending order of quantity, France, Germany, and Japan. Domestic imports of ferrozirconium alloys were 281 t in 2000, a 182% increase from the previous year. Imports originated primarily from Brazil, with a minor quantity from Germany. U.S. imports of unwrought hafnium metal and waste and scrap were 11.1 t, an 18% increase compared with those of 1999.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2000 is estimated to be 760,000 t, a minor increase compared with that of 1999 (table 5). Australia and South Africa supplied about 82% of all production outside the United States. World reserves of zircon are estimated to be 36 Mt of ZrO_2, while identified world resources of zircon were 65 Mt of ZrO_2. During 2000, the zirconium industry continued

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to be active in the exploration and development of mineral deposits on a global basis, particularly in Australia, Kenya, Mozambique, South Africa, and the United States. Iluka Resouces was the world's largest producer of zircon in 2000, with mines in Australia and the United States. Other major zircon producers in order of decreasing production were Richards Bay Minerals (RBM) of Australia, Namakwa Sands (Pty.) Ltd. of South Africa, DuPont of the United States, and Tiwest Joint Venture of Australia.

Australia.—Australia was one of the two largest producers of zircon concentrates in the world (table 5). In 2000, major producers of zircon concentrates, in order of estimated zircon production, were Iluka Resources (formerly RGC Ltd. and Westralian Sands Ltd.), Tiwest, Consolidated Rutile Ltd. (CRL), and Cable Sands Ltd. (CSL). Australian zircon production for 2000 was as follows: Iluka, 194,000 t; Tiwest, 91,000 t; CRL, 46,000 t; CSL, 30,000 t; and New South Wales producers, 4,000 t (Mineral Sands Report, 2001b). Total Australian production in 2000 was reported to be 353,000 t, a decrease from the 1999 level.

Worldwide production from Australian-based Iluka was 315,000 t of zircon in 2000, a decrease from the 331,000 t in 1999 (Iluka Resources Ltd., 2001, p. 9). The company operated eight mines in Australia and two in the United States. Iluka's Australian subsidiary, WA Titanium Minerals, operated six mines in Western Australia, two of which opened in 2000. The company commissioned the Capel North West Mine in January, near Capel, Western Australia. In October, WA Titanium brought online its second operation, the North Mine and Newman concentrator near Eneabba, Western Australia. Other mining operations were the South Mine near Eneabba and the Yoganup, Yoganup extended, and Busselton mines in the southwestern region. Iluka's two east coast mines, in which it has a 43% interest, were operated by CRL on North Stradbroke Island, New South Wales.

Iluka upgraded the ore grade at its Ouyen deposit in northwestern Victoria by 28%. The inferred resource at Ouyen was increased by 1.7 Mt to 7.7 Mt grading 11.4% heavy minerals and containing 40% ilmenite, 15% rutile, and 9% zircon (Iluka Resources Ltd., 2000).

Iluka calculated resources for two of its heavy-mineral sands deposits in the Perth Basin of Western Australia. The Red Gully deposit to the north and the Dandalup deposit to the south of Perth displayed resources of 942,000 t of heavy minerals (Iluka Resources Ltd., 2000).

Australian Zirconia Ltd., a wholly owned subsidiary of Alkane Exploration Ltd., announced it had produced a 99.3% zirconium oxide and hafnium oxide product from its Dubbo hard-rock zirconium-bearing deposit in New South Wales. DEMA Pty. Ltd. was the feasibility study manager and consultant for the project. The multimineral deposit is located on the Toongi alkaline intrusive that contains hafnium, lanthanides, niobium, tantalum, yttrium, and zirconium in the igneous rock trachyte. Based on a planned 200,000 t/yr sulfuric acid leach process, the plant was expected to produce 3,500 t/yr zirconium oxide (and hafnium oxide), 500 to 1,500 t/yr yttrium-lanthanide concentrate, and 900 t/yr tantalum-niobium pentoxide concentrate (Australian Zirconia Ltd., Dubbo zirconia project, accessed May 8, 2001, at URL http://www.alkane.com.au/zirconia.html).

Basin Minerals Ltd. announced the completion of a prefeasibility study of its Douglas heavy-mineral sands deposit discovered in the Murray Basin in western Victoria. The Douglas deposit covers an area of 5,860 square kilometers and has a resource of 22.4 Mt of heavy minerals. The area contains the Acapulco, Bondi, Bondi East, and Echo strandline deposits containing 11.3 Mt of ilmenite (including leucoxene), 1.26 Mt of rutile, and 1.62 Mt of zircon. The project has a projected startup date for 2003 (Basin Minerals, [undated], Mineral sands exploration overview—Douglas project, accessed May 2, 2001, at URL http://www.basinminerals.com.au/projects.html).

Basin Minerals explored five heavy-mineral sands deposits in the Murray Basin area of South Australia, Victoria, and New South Wales. The principal deposits were the Douglas project in Victoria, the Culgoa project in northern Victoria, the Baranald-Swan Hill in New South Wales and Victoria, the Oakville in northern South Australia, and the Pooncarie in western New South Wales. Total resources of the Douglas and Culgoa deposits were 24.4 Mt of heavy mineral concentrates contained in 393 Mt of ore grading 6.2% heavy minerals (Basin Minerals, [undated], Mineral sands exploration overview—Table 1, accessed May 2, 2001, at URL http://www.basinminerals.com.au/projects.html).

Basin Minerals acquired additional land adjacent to its Douglas deposit in Victoria. The State of Victoria awarded successful bids to Basin Minerals for block 2 in the Murray Basin which includes the former CRL WIM 100 deposit with 860 Mt of ore grading 5.9% heavy minerals (Mineral Sands Report, 2000c).

BeMaX Resouces NL announced the results of its pilot plant at its Ginkgo mineral sands joint venture (MSJV). The MSJV partners are BeMaX (50%), Imperial Mining (Aust) NL (25%), and Probo Mining Pty. Ltd. (25%). Located 120 kilometers (km) north of Mildura, Victoria, the Ginkgo deposit has an inferred resource of 260 Mt grading 2.6% heavy minerals. Initial tests showed product suitable for market including ilmenite, rutile, leucoxene, and zircon (BeMaX Resources NL, April 3, 2000, Update—Ginkgo mineral sands deposit, accessed March, 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

BeMaX purchased Imperial Mining's 25% share of the MSJV, raising BeMaX's holdings to 75%. Imperial Mining was a wholly owned subsidiary of Imperial One Ltd. (BeMaX Resources NL, October 10, 2000, Completion of purchase of Imperial Mining (Aust) NL, accessed March 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

BeMaX released information on a heavy mineral strandline discovery that straddles BeMaX's BIP joint-venture property and the property of Iluka Resouces in the Murray Basin. The adjacent Snapper (BeMaX) and Trelega (Iluka) deposits straddle the mining exploration claims at the southwest edge of the BIP joint venture EL5474 property in Victoria (BeMaX Resources NL, October 10, 2000, Mineral Sands discovery straddles boundary of BeMaX's and Iluka's properties, accessed March 13, 2001, via URL http://www.bemax.com.au/Announcements00.html).

Mineral Deposits Ltd. (MDL) stated that it would restart its Viney Creek dredge mine in New South Wales in 2001 because of increased demand for heavy minerals and a weak Australian dollar against the U.S. dollar. The 2,500-ton-per-hour dredge was placed on standby in April 1999 because of weak demand for rutile and zircon. The dredge will be refurbished in the last quarter of 2000. MDL's Hawks Nest dry mill continued to operate with feed from its smaller dredge operation at Fullerton,

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New South Wales (Mineral Sands Report, 2000e).

Tiwest, an Australian collaboration of U.S.-based Kerr McGee Chemical's LLC subsidiary KMCC Western Australia Pty. Ltd. and Australian-based Ticor Resources Pty. Ltd., produced zircon from its Cooljarloo Mine in Western Australia. In 2000, Tiwest processed 918,000 t of heavy-mineral concentrates to produce 91,000 t of zircon, compared with 548,498 t of heavy-mineral concentrates and 60,188 t of zircon produced in 1999 (Minerals Sands Report, 2001c). The large increase in production was the result of the Cooljarloo Mine upgrade project in 2000. The capacity of heavy-mineral concentrates was increased to 675,000 t/yr from 535,000 t/yr, a 20% gain. Tiwest's expansion cost was 20 million Australian dollars ($A) and was designed and implemented by contractor HBH Consultants (The Institution of Engineers, Australia, 2001, Australian engineering awards 2000—Cooljarloo mine upgrade project for the Tiwest joint venture, accessed March 22, 2001, at URL http://www.ieaust.org.au/events/aeea_entrants/aeea_entrantdetails8.html).

RZM Pty. Ltd. purchased Western Metals Ltd.'s 30% stake in the Wemen heavy-mineral sands project in the Murray Basin, Victoria, for $A5 million. Following the buyout, RZM entered into a 50-50 joint venture with the Australian company Sons of Gwalia for its Murray Basin mineral resource tenements and freehold land and a 50% share of RZM's heavy-mineral sands processing equipment and operations at Tomago, New South Wales. Production from the deposit is scheduled for 2001. Wemen is forecast to produce 10,000 t/yr of zircon over the mine's 6-year life (Industrial Minerals, 2000a).

Brazil.—Millennium Inorgânica Chemicals do Brazil S/A announced it would invest $31 million to upgrade its heavy-mineral sands output at its Mataraca Mine at Guaju, Paraiba State. The installation of a new dredging operation is expected to improve recoveries and lower overall operating costs. The upgrade was expected to be completed by yearend 2001 (Industrial Minerals, 2000f). In 1999, the mine produced about 110,000 t of ilmenite, 2,000 t of rutile, and 16,000 t of zircon (Titanium Minerals Outlook, 2000b). Millennium Inorgânica Chemicals do Brasil S/A produced 61.5% of the zircon concentrate mined in Brazil in 1999. Total Brazilian production of zircon in 1999, the latest available preliminary data, was 29,448 t (Esteves dos Reis, 2001).

Other zircon producers in Brazil are operated by Industrias Nucleares do Brasil S/A (INB), a wholly owned subsidiary of Comissa Nacional de Energia Nuclear. INB produces up to 9,800 t/yr of zircon from its mines in Buena and Delta Paraíba in Rio de Janeiro, Cumuruxatiba in Joacema, and Alcobaça in Bahia.

China.—Production of zircon is estimated to be 20,000 t or less in 1999, which were the latest available data. China was a net importer of zirconium materials in 1999, importing 131,000 t with 73% as zircon concentrates, 18% as bagged zircon or flour, 8% as opacifiers, and 1% other. The principal market for zircon in China is ceramics with an estimated 60% share of the market. Milling capacity is estimated to be 74,000 t/yr and is located mainly in Guangzhou Province, the center of China's ceramic industry. Nanhai is the largest producer of zircon flour with a capacity of 15,000 t/yr out of an estimated 50,000 t/yr capacity. The principal producers of opacifiers are Atofina Chemicals, Inc., and China Glaze Co. Ltd. Total opacifier capacity is estimated to be 24,000 t/yr (Mineral Sands Report, 2000a).

CRL announced the sale of its Chinese-based milling plant, Changzhou Dongao Zirconium Products Ltd., to Johnson Matthey plc in November. The mill has a capacity of 5,000 t/yr. Johnson Matthey plans to upgrade the facility, raise capacity, and install equipment for tile products (Mineral Sands Report, 2000b)

Deqing Biochemistry General Co. (DBGC) announced it was producing zirconium chemicals, including zirconium oxychloride, carbonate, sulfate, acetate, and dioxide, from its plant in Deqing, Zhejiang Province. Capacities for DBGC's zirconium products were 750 t/yr for zirconium oxychloride, 300 t/yr for zirconium carbonate, and 300 t/yr for zirconium sulfate. An expansion in 2001 is expected to increase DBGC's zirconium compound capacity to 15,000 t/yr (Jiang Dongming, Deqing Biochemistry General Corp., written commun., 2001).

India.—Indian Rare Earths Ltd. (IRE) was the eighth largest producer of zircon in the world from its mine at Chavara. IRE produced 22,000 t of zircon in 2000 (Mineral Sands Report, 2001c).

MDL and Iscor Ltd. have signed a memorandum of understanding to form an alliance to develop two heavy-mineral sands deposits in Tamil Nadu State. The Tamil Nadu deposits at Kudiraimozhi and Navaladi-Sattankulam contain 1 billion metric tons of ore grading 6.2% ilmenite, 0.4% rutile, and 0.7% zircon (Mineral Deposits Ltd., November 1, 2000, Announcements—Indian mineral sands project, accessed June 14, 2001, via URL http://www.mineraldeposits.com.au/Announcements2000.html).

Kerala Minerals and Metals Ltd. (KMML) is planning an expansion of its operations at Chavara. KMML has reserves of 18 Mt grading up to 50% heavy minerals. The heavy minerals contain 65% to 75% ilmenite, 5% to 7% rutile, and 4% to 8% zircon (Titanium Minerals Outlook, 2000a).

Kenya.—Tiomin Resources Inc. of Toronto, Canada, raised Can$5 million through the private offering of warrants for investments in its Kwale heavy-mineral sands deposit. The cash was expected to be used to acquire surface mining rights at its Kwale deposit and to finalize detailed engineering plans for the heavy-mineral sands mine (Mineral Sands Report, 2000g). The Kwale deposit is divided into three economic zones of Pliocene age: the north, the central, and the south dunes. Zircon and other heavy minerals are contained in the Magarini Formation sands, which form a belt of low hills believed to be aeolian in origin. Resources of the Kwale deposit are 200 Mt of ore containing 0.6 Mt of zircon (Tiomin Resources Inc., [undated], Kwale—Rutilite, ilmenite, and zircon, accessed May 16, 2001, via URL http://www.tiomin.com/s/Properties.asp?PropertyInfoID=316&PropertyMapID=1034).

Based on the results of a feasibility study by LTA Process Engineering Pty. Ltd. of South Africa and Ausenco of Australia, Tiomin planned to start construction at Kwale in 2001. During its first 6 years, the mine is expected to produce 37,000 t/yr of zircon. Kwale has a mine life of 14 years (Industrial Minerals, 2000e).

Mozambique.—Kenmare Resources plc of Dublin, Ireland, bought the heavy-mineral sands dry separation plant from BHP Ltd's Beenup Mine in Western Australia, which closed in 1999 after being in operation less than a year (Industrial Minerals, 2000d). The 650,000 t/yr plant was purchased for $4.7 million and is expected to be installed at the Moma titanium minerals project in Mozambique (Kenmare Resources plc, 2000a).

Kenmare had previously purchased BHP's wet concentrator in January for $1.4 million (Industrial Minerals, 2000c). The aquisition of both plants from the Beenup minesands project is

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expected to save Kenmare in excess of $60 million in capital expenditures. The Moma titanium project is scheduled to begin production in late 2002 (Kenmare Resources plc, 2000b)

South Africa.—Iscor Ltd. announced it would begin development of its Hillendale Mine in Kwazulu Natal Province in the second quarter of 2001. The initial production capacity of the mine will be 50,000 t/yr of zircon but will increase to 100,000 t/yr by 2003. Other heavy mineral capacities, at full production, are 550,000 t/yr for ilmenite, 40,000 t/yr for rutile, and 10,000 t/yr for leucoxene. Reserves at the Hillendale deposit are 73 Mt grading 5.6% valuable heavy minerals, excluding magnetite (Iscor Ltd., [undated], Heavy minerals—Hillendale, accessed April 22, 2001, via URL http://www.iscor.com/mainframe.asp?imgname=01). Construction of the Hillendale mine and wet concentrator plant began in April at a cost of $137 million. Construction also began on a central mineral separation plant at Empangeni, 20 km from the mine site. The separation plant was expected to come onstream in the third quarter (Industrial Minerals, 2000b).

Ticor Ltd. announced in October that it has begun a review of Iscor's heavy-mineral sands deposits in South Africa. Ticor is interested in acquiring a 50% share of the project, which has reserves of 16 Mt of heavy minerals. The project consists of three deposits: the Hillendale, the Fairbreeze, and the Gravelotte. The Hillendale is scheduled to be the first mine developed. The combined mine life of the three deposits is at least 20 years (Mineral Sands Report, 2000f).

Foskor Ltd. commissioned a third zircon smelting furnace for the production of zirconia with a capacity of 1,500 t/yr. Total zirconia capacity of the three operations is 5,000 t/yr. In addition to producing synthetic zirconia from zircon, Foskor produced an estimated 2,000 to 3,000 t of baddeleyite (natural zirconia) from its Palabora Mine at Phalaborwa in 1998, which were the latest available data. The company ceased production of baddeleyite in June 1999 as a result of declining ore grades (Industrial Minerals, 2000g).

Namakwa Sands, a wholly owned subsidiary of Anglo American plc, increased its heavy-mineral sands production as a result of the completion of its phase two expansion. Construction of the project, which was funded at 1.2 billion rand (R) in 1997, was completed in 1999. Zircon was produced from its mine at Brand-se-Baai. Zircon concentrate produced from its dry mill at Koekenaap increased to 106,800 t in 2000 from 91,900 t in 1999 (Mineral Sands Report, 2001a). The phase two expansion increased ore capacity to 12 million metric tons per year (Mt/yr) from 4 Mt/yr. Zircon capacity increased to 133,000 t/yr with a mine life of 35 years.

Amagamet Canada, a division of Premetalco Inc., was the North American sales agent for Namakwa Sands of South Africa. Amagamet reported the purity of the Namakwa South Africa zircon to be 66% minimum, ($ZrO_2 + HfO_2$), 0.06% maximum (Fe_2O_3), and 0.12% maximum (TiO_2) (Amagamet Canada, [undated], Zircon, accessed June 14, 2001, at URL http://www.amalgamet.com/busmizi.htm).

Palabora Mining Co. Ltd. continued to produce baddeleyite from its open pit mine. Open pit mining at the Palabora Mine is scheduled to cease in 2002, and the company will begin recovering ore by underground mining methods. In 1999, the latest available data, Palabora produced 7,486 t of baddeleyite, an 8% decrease from 1998. The decreased production was attributed to a decline in ore grade with increasing depth of the pit. Palabora also produced zirconium sulfate tetrahydrate and milled baddeleyite (Palabora Mining Co. Ltd., 2000, p. 9).

RBM completed construction of a new heavy-mineral sands processing plant. Completed in October 1999, the plant is designated mining plant E (Joseph, 2001).

Outlook

The global demand for zirconium materials was largely in balance in 2000. Growth was expected to increase by 3% per year over the next few years, and new deposits are expected to come online. Prices were forecast to rise in the near term in response to higher energy costs. During the next few years, however, the supply and demand of zircon is expected to be in closer balance as new deposits and plant expansions come online, especially in the United States and Australia. Expansions in supply are expected in Mozambique and South Africa, and further exploration and development efforts are underway in Australia, Canada, India, Kenya, South Africa, Ukraine, and the United States. Production of zircon in the United States was expected to increase during the first decade of the 21st century.

References Cited

Esteves dos Reis, Ananias, 2001, Zircônio: Sumário Mineral 2000, Brasilia, Brazil, Departmento Nacional de Produção Mineral, p. 119-120.

Iluka Resources Ltd., 2000, Quarterly report—1st quarter]: Perth, Australia, Iluka Resources Ltd., April 20, p. 3-4.

———2001, 2000 annual report: Perth, Australia, Iluka Resources Ltd., 40 p.

Industrial Minerals, 2000a, Gwalia/RZM j-v for Murray Basin: Industrial Minerals, no. 390, March, p. 13-14.

———2000b, Iscor gives go-ahead to Hillendale minsands: Industrial Minerals, no. 392, May, p. 12-15.

———2000c, Kenmare buys BHP minsands plant: Industrial Minerals, no. 389, February, p. 11-14.

———2000d, Kenmare buys second Beenup plant: Industrial Minerals, no. 393, June, p. 15-17.

———2000e, Kwale minsands feasibility update: Industrial Minerals, no. 393, June, p. 15.

———2000f, MIC in $31m. upgrade of ilmenite mine: Industrial Minerals, no. 390, March, p. 14.

———2000g, Third zirconia smelter for Foskor: Industrial Minerals, no. 393, June, p. 17.

Joseph, K.R., 2001, Zirconium in South Africa's mineral industry 1999/2000: Department of Minerals and Energy, Republic of South Africa, p. 95-97.

Kenmare Resources plc, 2000a, Kenmare buys mineral separation plant for Moma Titanium: Kenmare Resources plc press release, May 3, 1 p.

———2000b, Kenmare Moma project granted favorable tax status: Kenmare Resources plc press release, December 20, 1 p.

Mineral Sands Report, 2000a, China—An emerging titanium industry: Mineral Sands Report, no. 61, November, p. 5-7.

———2000b, CRL sells Chinese milling plant to Johnson Matthey: Mineral Sands Report, no. 62, December, p. 2.

———2000c, Exploration—Murray Basin tender: Mineral Sands Report, no. 61, November, p. 2.

———2000d, Iluka Resources exceeds revised profit forecast for 1999: Mineral Sands Report, no. 54, April, p. 3.

———2000e, New sales and weak $A prompt Mineral Deposits to restart Viney Creek dredge: Mineral Sands Report, no. 61, November, p. 3.

———2000f, Ticor re-examines Iscor project: Mineral Sands Report, no. 61, November, p. 1.

———2000g, Tiomin raises $5 million: Mineral Sands Report, no. 61, November, p. 2.

———2001a, Namakwa Sands reports higher production in 2000: Mineral Sands Report, no. 66, April, p. 3.

———2001b, Production increases in 2000: Mineral Sands Report, no. 65, March, p. 10-13.

———2001c, Ranking the TiO_2 and zircon industries: Mineral Sands Report, no. 67, May, p. 4-6.

Palabora Mining Co. Ltd., 2000, Annual report 1999: Palabora Mining Co. Ltd., South Africa, 46 p.

Titanium Minerals Outlook, 2000a, Supply—Kerala Minerals and Metals Ltd.: Titanium Minerals Outlook, February, p. 4.

———2000b, Supply—Millennium: Titanium Minerals Outlook, February, p. 6.

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Zirconium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Zirconium. International Strategic Minerals Inventory Summary Report, Circular 930-L, 1992.
Zirconium and Hafnium. Ch. in Mineral Commodity Summaries, annual.

Other

American Metal Market, daily.
Chemical Engineering, biweekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
Industrial Minerals [London], monthly.
International Titanium Association.
Metal Bulletin [London], semiweekly.
Mineral Sands Report, bimonthly and monthly.
Mining Engineering, monthly.
Mining Magazine and Mining Journal [London], monthly and weekly.
Roskill Information Services Ltd. [London].
U.S. Department of Commerce, U.S. Census Bureau, monthly trade statistics.
Zirconium and Hafnium. Ch. In Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS 1/

(Metric tons)

	1996	1997	1998	1999	2000
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	55,300	55,700	55,700	55,600	56,200
Exports	35,000	44,300	41,000	69,500	72,900
Imports for consumption 2/	92,500	62,400	89,500	57,600	65,200
Consumption, apparent 2/	W	W	W	W	W
Stocks, December 31, dealers and consumers 3/	34,300	29,300	32,000	24,700	25,100
Zirconium oxide:					
Production 4/	15,000	15,900	17,300	17,100	22,900
Exports 5/	1,480	1,970	1,540	1,680	2,220
Imports for consumption 5/	5,240	4,220	3,900	3,140	3,950
Consumption, apparent	W	W	W	W	W
Stocks, December 31, producer 4/	822	982	985	W	818 e/

e/ Estimated. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits.
2/ Includes insignificant amounts of baddeleyite.
3/ Excludes foundries.
4/ Excludes intermediate oxides associated with metal production.
5/ Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	1999	2000
Zircon:		
Domestic, standard-grade, bulk, per short ton 1/	$300.00 r/	$340.00
Domestic, 75% minimum quantity zircon and aluminum silicates, bulk, per short ton 1/	267.00	267.00
Domestic, premium-grade zircon, bulk, per short ton 1/	490.00	497.00
Imported sand, ceramic application, f.o.b., bulk, per metric ton 2/	320.00-360.00	345.00-375.00
Imported sand, refractory application, f.o.b., bulk, per metric ton 2/	320.00-360.00	340.00-370.00
Imported sand, foundry sand application, f.o.b., bulk, per metric ton 2/	320.00-360.00	340.00-370.00
Zirconium: 5/		
Powder, per pound	75.00-150.00	75.00-150.00
Sponge, per pound	9.00-12.00	9.00-12.00
Sheets, strip, bars, per pound	20.00-50.00	20.00-50.00
Hafnium, sponge, per pound 5/	75.00-95.00	75.00-95.00

See footnotes at end of table.

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TABLE 2--Continued
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	1999	2000
Baddeleyite, imported concentrate: 3/		
98% to 99% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	1.23	--
Over 99% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	1.36	0.98
Zirconium oxide: 4/		
Powder, commercial-grade, drums, 2,000-pound minimum, per pound	3.00-6.60	3.00-6.60
Electronic, same basis, per pound	3.66-7.50	3.66-7.50
Insulating, stabilized, 325° F, same basis, per pound	4.00	4.00
Insulating, unstabilized, 325° F, same basis, per pound	4.00	4.00
Dense, stabilized, 300° F, same basis, per pound	4.20	4.20

r/ Revised. -- Zero.

1/ Domestic average price.

2/ Industrial Minerals (London), no. 387, December 1999, p. 71; no. 399, December 2000, p. 75.

3/ American Vermiculite Corp. baddeleyite price lists.

4/ Chemical Marketing Reporter, v. 256, no. 26, December 27, 1999, p. 25; v. 258, no. 25, December 18, 2000, p. 29.

5/ American Metal Market, v. 107, no. 251, December 31, 1999, p. 6; v. 108, no. 250, December 29, 2000, p. 9.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY 1/

	1999		2000	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates:				
Afghanistan	--	--	137	$61
Argentina	652	$412	507	281
Australia	40	23	73	43
Belgium	3,390	1,020	6,190	2,400
Brazil	1,030	542	910	417
Canada	4,240	1,980	6,420	2,920
Chile	221	147	431	257
China	2,960	1,240	872	390
Colombia	2,240	1,440	2,430	1,480
Costa Rica	97	85	--	--
Dominican Republic	254	209	215	162
Ecuador	532	336	957	495
France	2,100	1,210	1,000	657
Germany	4,370	1,730	993	1,210
Guatemala	98	82	78	59
Hong Kong	104	65	60	37
Hungary	15	4	--	--
India	3	3	49	24
Indonesia	117	65	215	108
Ireland	427	306	124	118
Israel	37	54	329	467
Italy	16,900	5,140	23,000	7,600
Japan	993	400	1,510	778
Korea, Republic of	16	12	562	208
Malaysia	59	32	--	--
Mexico	3,920	1,520	14,800	3,710
Netherlands	16,500	4,830	5,130	1,710
Pakistan	670	422	551	333
Panama	--	--	31	6
Philippines	276	164	178	103
Portugal	44	48	36	44
Singapore	19	10	--	--
Sri Lanka	19	13	--	--
Sweden	34	22	34	22
Switzerland	57	32	34	22
Taiwan	187	115	133	106
Thailand	119	67	40	24
United Arab Emirates	176	99	--	--
United Kingdom	5,160	2,570	3,790	7,040
Venezuela	1,350	849	900	543
Vietnam	59	37	179	138

See footnotes at end of table.

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TABLE 3--Continued
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY 1/

Class and country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Ore and concentrates--Continued:				
Other	6 r/	$10 r/	5	$20
Total	69,500	27,300	72,900	34,000
Unwrought zirconium and waste and scrap:				
Canada	11	544	5	190
Japan	56	959	48	1,010
United Kingdom	64	1,020	111	1,550
Other	25 r/	635 r/	16	872
Total	156	3,160	180	3,620

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY 1/

Class, harmonized code, and country	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Zirconium ore and concentrates: (2615.10.0000)				
Australia	23,800	$6,770	31,600	$9,020
Austria	38	13	--	--
Belgium	--	--	20	43
Canada	27	42	50	58
China	--	--	41	136
Germany	107	143	391	510
Italy	3,560	2,540	2,330	1,390
Japan	38	28	553	3,420
Mexico	--	--	240	189
Netherlands	448	403	120	82
Russia	26	66	42	105
South Africa	29,400	7,440	29,400	9,410
Ukraine	80	38	--	--
United Kingdom	102	416	394	1,320
Other	(2/)	8	18	119
Total	57,600	17,900	65,200	25,800
Zirconium, unwrought and waste and scrap: (8109.10.3000, 8109.10.6000, 8109.90.0000)				
Argentina	--	--	21	333
Canada	53	1,990	56	4,030
China	31	510 r/	17	314
France	596	25,100	665	26,600
Germany	118	18,000	179	20,200
Japan	32	479	79	458
Other	29	610	24	664
Total	859	46,700	1,040	52,700
Hafnium, unwrought and waste and scrap: (8112.91.2000)				
Belgium	1	$191	--	--
Canada	1	245	1	$340
France	6	1,060	8	1,440
Germany	(2/)	238	1	415
Japan	--	--	I	38
Russia	1	30	(2/)	11
Total	9	1,770	11	2,240

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Australia	502,000	424,000	404,000	400,000	353,000 3/
Brazil 4/	15,560	19,252	19,300	19,500	19,500
China e/	15,000	15,000	15,000	15,000	15,000
India e/	19,000	19,000	19,000	19,000	19,000
Indonesia	2,000 e/	105	231	250	250
Malaysia	4,511	4,050	3,057 r/	1,763 r/	2,000
Russia 5/	5,080	5,745	6,293	6,800	6,500
South Africa e/ 6/	260,000	265,300 3/	265,000 r/	219,000 3/	270,000
Sri Lanka	15,863	12,450	8,814 r/	-- r/	--
Thailand	5	--	-- e/	-- r/	--
Ukraine e/	55,000	65,000	65,000	69,000 r/	75,000
United States	W	W	W	W	W
Total	894,000	830,000	806,000 r/	750,000 r/	760,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits.

2/ Includes data available through May 11, 2001.

3/ Reported figure.

4/ Includes production of baddeleyite-caldasite.

5/ Production of baddeleyite concentrate averaging 98% ZrO_2.

6/ Includes production of byproduct zircon from titanium sands mining and 15,000 to 20,000 metric tons per year baddeleyite from Palabora Mining Co. Ltd.

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